Title: A Knowledge Building Approach to Primary Science Collaborative Inquiry supported by Learning Analytics.

Abstract:

This case study explores how a science teacher adopted Knowledge Building and Learning Analytics to support a class of primary five students to collaboratively inquire and learn about electricity. Specifically, we aim to understand how the teacher implemented a lesson design guided by Knowledge Building principles of idea improvement and community knowledge and how he used visualisations from an analytics tool to facilitate students in collaborative inquiry in Science. We collected student notes from online discourse in Knowledge Forum and video-recorded a total of 11 lesson videos and conducted interviews with the teacher and students. We found that students' online discussion reflected *explanation-seeking* questions to sustain the inquiry on the topic and elaborated explanations to deepen and improve their ideas on concepts of electricity. We also found that the visualisations from learning analytics supported (i) teacher-facilitated whole-class discussions on curriculum keywords and student ideas to develop conceptual understanding and idea-building, and (ii) students in exploring science ideas they were interested in. The findings from our study contribute to the understanding of teachers' enactment of inquiry-supported pedagogies in primary science classrooms.

Keywords – Collaborative inquiry in Science, Knowledge Building, Learning Analytics, Student discourse, Electricity, Idea improvement

## Introduction

Science education in K-12 classrooms aims to promote students' scientific inquiry (Christodoulou & Osborne, 2014). Scientific inquiry requires authentic scientific practices that give students opportunities to explore and develop their knowledge and understanding of scientific ideas and to help them appreciate how scientists investigate the natural world (NRC, 2012). There have been various efforts to understand inquiry-supported pedagogies that align with authentic scientific practices. In particular, Knowledge Building (KB) has been found effective in promoting student-driven collaborative inquiry in Science through collective idea improvement to explore and discover real-world science understanding (Tao & Zhang, 2018). While it has been known that KB has positive influences on students' understanding of science, how teachers should adopt and practise KB in classrooms to support student-driven collective idea improvement is still underexplored (Li, Hong, Chai, Tsai & Lin, 2018). The understanding of such practices with the use of Learning Analytics (LA) is also less informed. This paper attempts to contribute to this understanding by reporting a case study of a teacher's practice with his primary five students in collective idea improvement to promote collaborative inquiry in Science.

## Knowledge Building and collaborative inquiry in Science

Knowledge Building (KB) is an established theory in the learning sciences that has gained prominence among researchers for supporting collaborative learning in science classrooms (Chen, 2016; Hong & Lin, 2019; Lin & Chan, 2018a; 2018b; Tao

& Zhang, 2018, Zhang & Sun, 2011; Zhang, Scardamalia, Reeve, & Messina, 2009; Zhang, Tao, Chen, Sun, Judson & Naqvi, 2018). A central tenet of KB is the notion of collective idea improvement, which has been shown to benefit young students in elementary science classrooms. For example, Zhang and Sun (2011) documented that grade 4 (year 4) students demonstrated productive advancement (improvement) of scientific understanding on the topic of light when engaged in a KB environment. Similarly, Tao and Zhang (2018) showed that a community of grade 5 students learnt to co-construct shared structures of inquiry about human body systems and improved in science understanding when engaged in ongoing discussions and reflections in Knowledge Forum (KF). Thus, when students have opportunities to explore, discover and advance new knowledge with their peers, they are likely to achieve beyond individual knowledge gains (Scardamalia, 2002). Although studies have reported positive influences of KB on students' understanding of science, how teachers should adopt and practise KB in classrooms to support student-driven collective idea improvement is still underexplored (Li, Hong, Chai, Tsai & Lin, 2018).

In practice, KB is supported by an online environment called Knowledge Forum (KF), a web-based discussion forum to archive student ideas and allow them to trace their idea development (Scardamalia, 2002). KF provides a communal space where students' ideas, reference materials, results of experiments, and other information are recorded and archived for continual refinement, so that students can engage in questioning, building on, reasoning with, refining and synthesising each others' ideas to deepen the knowledge and understanding. This collective idea improvement process also support students in collaborative inquiry in Science as they have opportunities to find out and seek evidence to build on the knowledge that is of interest to them. Furthermore, when students decide which ideas to investigate and to improve, they are more inclined to take on ownership and agency of learning and an open approach to the science inquiry (Banchi & Bell, 2008).

Researchers have attempted to characterise the quality of students' Knowledge Building discourse in KF. For instance, Lai and Law (2013) explored the quality of questions from threads of student KF notes. A KF thread "registers discussions around a theme, and is often the location where collective knowledge advancement can be most easily traced" (Lai & Law, 2013, p. 601). They found that the students asked *fact-seeking* and *explanation-seeking* questions, and concluded that *explanation-seeking* questions contributed more to advancing knowledge. More recently, Lin and Chan characterised students' threads into epistemic patterns based on theory building moves (Lin & Chan, 2018a). These theory building moves included *fact-seeking* and *explanation-seeking* questions and also whether students provided deep explanations to improve their understanding of the topic. The researchers found that productive threads reflected sustained inquiry and theory building that focused on the idea-driven aspect of science by constructing ever-deeper explanations of the natural world (ibid). From these studies, a thread-level analysis is a viable way to help us understand the extent students' idea-building discussions can be a mechanism for collective idea improvement (Zhang et. al., 2009). However, as students' ideas increase in diversity of perspectives, they need support in understanding the idea development so as to engage meaningfully in the discussions (Scardamalia, 2002).

The need for students to understand their idea development in KF have led researchers to explore Learning Analytics (LA) to provide such support (Chen, 2016;

Chen, & Zhang, 2016; Hong & Lin, 2019; Matsuzaw, Oshima, Oshima, Niihara & Sakai, 2011). Generally, LA provides analyses, visualizations, and summaries of student data that can be used for student feedback and to help teachers to be better able to identify problems with participation and to provide necessary support for student learning (van Leeuwen, 2015; van Leeuwen, Janssen, Erkens & Brekelmans, 2014). In KB, researchers have attempted to utilize LA to see idea trajectories in various ways. For example, Zhang and colleagues (2018) explored LA to visualise connections across threads of diverse topics and from different class communities for further inquiry. Chen and Zhang (2016) looked at an analytic tool to support students' judgments for promisingness of their ideas to support ongoing idea improvement. Hong and Lin (2019) utilised LA to see connections between keywords from student KF discourse. Buidling on these efforts, we further hypothesise that keywords from student KF discourse benchmarked with curriculum ideas can support students to expand idea development in breadth and depth of the curriculum. However, LA development in KB is still emerging and there is a need for research to understand students' use of and teachers' intervention with LA in classrooms (van Leeuwen, 2015; Zhang et al., 2018). To build on the understanding of collective idea improvement in KB with the use of LA, we explore a case study of a lesson design with Knowledge Building principles and a Learning Analytics incorporating curriculum ideas to support students' collaborative inquiry in Science.

## Research design and methodology

We employed a descriptive qualitative case study to obtain an in-depth understanding of the teacher's practice and students' engagement in KF from an intervention lesson design. Translation of KB into classroom practice requires a consideration of KB principles (Scardamalia, 2002). Two key principles explored in this paper are community knowledge and idea improvement. In community knowledge, every student recognises the importance of community learning over individual learning and takes responsiblitiy to contribute ideas of value to others to deepen the collective understanding. In idea improvement, students view every ideas as improvable and collectively improve ideas through an ongoing process of questioning, refining and synthesizing ideas (ibid). Our lesson design incorporated a real electrical setup and the use of KF to support students in community knowledge and idea improvement. Specifically, we planned the lessons to support these students' KB processes: Idea generation, Idea connection, Idea improvement and Rise above.

### Idea generation

At the start, the teacher designed an extended inquiry around an authentic science problem. Students assembled a blinking light circuit using a commercial educational kit. Figure 1 shows the setup which comprised an electromagnet, a metal bridge (pole), bulb, switch and battery. Students had not learned all the topics and concepts involved in the activity but the task challenged them to reason out the process based on the knowledge regarding electrical circuits and current through trial and error. KF served as a discussion platform for students to post initial ideas and questions, and to hypothesise problems and solutions.

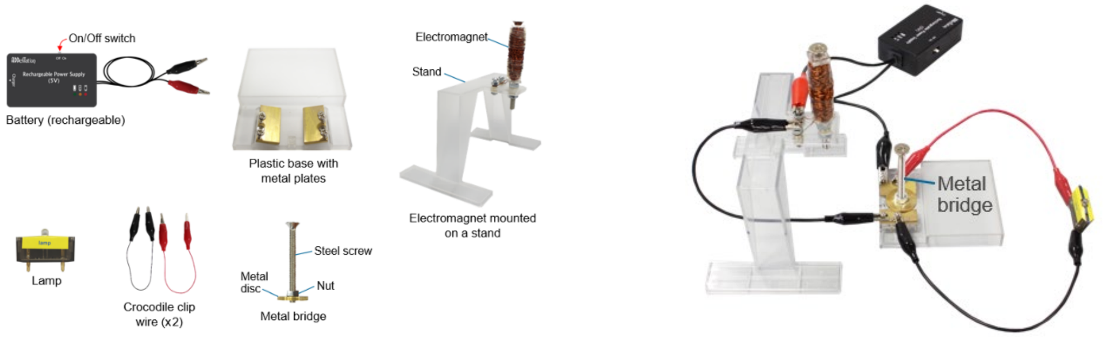


Figure 1. Components of blinking light circuit (left); Student task to assemble the blinking light setup (right)

Idea connection and improvement

The lesson design focused on creating the opportunities and time for students to connect ideas and to see shared problems and collective understanding. Specifically, KF served as ongoing discussion platform for the teacher and students to respond and build ideas and questions from the class. This allowed students to generate problems of understanding and make connections to their intuitive understanding of the problem. The discourse facilitation involved the teacher (i) acknowledging all contributions; (ii) encouraging every student to participate in the inquiry and ii) using analytics feedback (CiA) to help students identify words of interest in their discussion. Students also get to continually revisit, revise and refine their ideas, allowing them to deepen their understanding. Specifically, time was planned for students to test their improved ideas using the kit (3 or 4 trials) and to post improved ideas, new explanations or solutions, new problems and questions on KF. The discourse facilitation involved the teacher (i) using KF to let students examine knowledge gaps, formulate reasons and explanations; and (ii) using analytics feedback to help students see emerging keywords and identify promising ideas for further inquiry.

Rise above

The lesson design included opportunities for students to do a summary of learning by reflecting on their ideas at different check-points of the discussions. Here, KF allowed students to review all their ideas posted in the discussions and to post a “Rise above” note. The “Rise above” notes let students generate a deeper formulation of their understanding of the topic such as synthesising key ideas together by using the KB scaffold “Putting our knowledge together”.

Online discourse: Knowledge Forum and Curriculum-ideas Analytics

A key part of the intervention was the use of KF and LA to support idea improvement in the online student discussion. In this study, the teacher created a few KF views to let students generate and build on their ideas. Figure 2 shows a sample KF view and how student notes are captured. Each node (square box) represents a student’s idea (such as questions, explanations, information) and a build on note is connected by an arrow sign (indicating the direction of build on). Hence, the teacher can examine students’ build on notes to see how they develop the topic understanding and he could also post questions or comments to support further discussion. The KB scaffolds provided additional support to the students for idea improvement. The KB scaffolds are a set of customizable sentence starters that students can use for idea-buildng. In this study, we used a set of 6 KB scaffolds including “My idea is”, “I need to understand”, “A better idea is”, “This idea does not explain”, “New information” and “Putting our knowledge together” (Figure 2). These scaffolds were intended to help students to generate an idea, initiate an inquiry (or provide a clarification), add new information, reason their ideas and summarise different ideas.

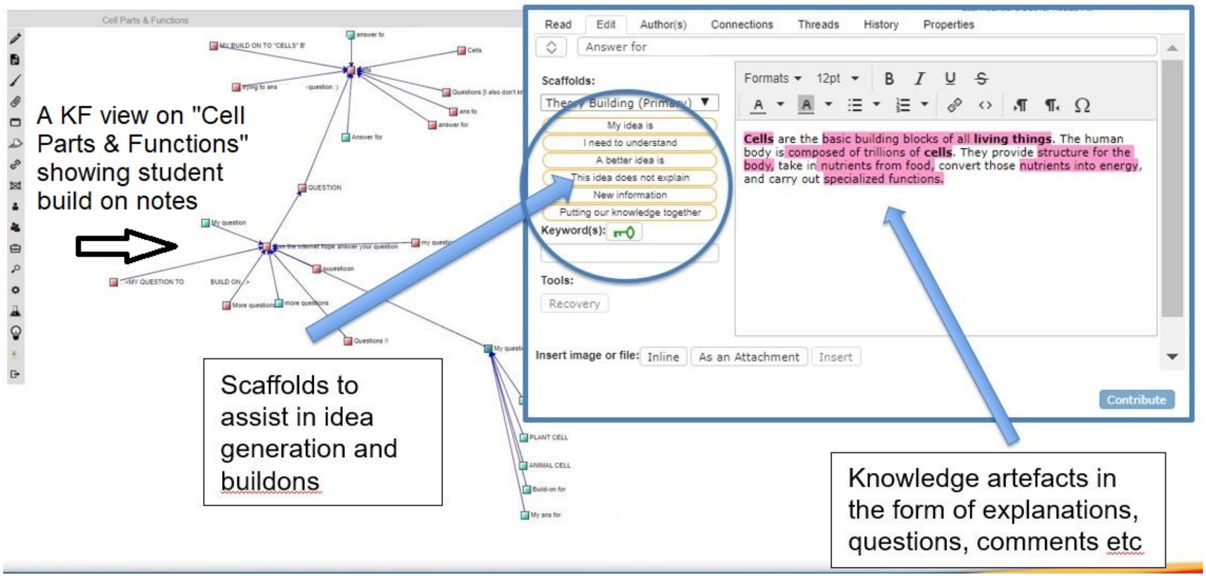


Figure 2. A KF view on “Cell Parts and Functions” showing student build on notes

The Curriculum-ideas Analytics (CiA) was developed jointly with the University of Albany as a tool to support the teacher to benchmark student-generated ideas against key concepts from curriculum to support idea development towards unifying themes and big ideas in Science. The curriculum included the national science syllabus for primary, secondary and junior college (elementary to year 12). CiA has a back-end machine that compares ideas from student notes posted on KF with the keywords mapped across elementary to year 12 science curriculum of the same topic. CiA provided feedback in the form of wordcloud visualizations whereby the teacher and students could quickly identify different ideas related to curriculum or extending beyond the curriculum. Figure 3 illustrates the analytics interface. A wordcloud showing the comparison of ideas from student discussion in a KF view to key concepts on electricity from the primary curriculum. The intervention involved the teacher using the wordcloud feedback to help students uncover word patterns from ideas and to review content from student notes to better identify promising ideas. For instance, the teacher can prompt for keywords from students about their discussion and use CiA to search for and identify student notes for further discussion (Figure 3).

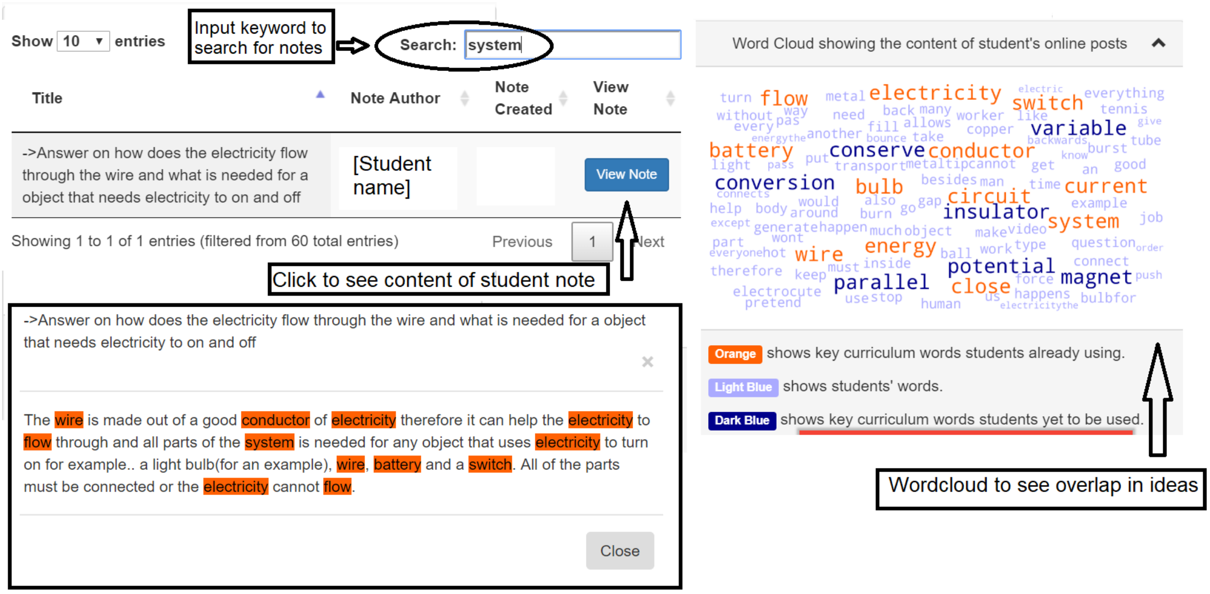


Figure 3. CiA interface.

Based on this lesson design and the analytic tool, our research questions include: i) How did students contribute to the discussions to support idea improvement? ii) How did the teacher utilise the CiA to support students in idea improvement and what were the teacher's and students' perceptions about the analytics support?

## Participants and contexts

The study was conducted from over a term (July to Oct 2019) in a girls' school in Singapore. Our participants involved a science teacher and 25 primary five (year 5) students. The teacher had 8 years of teaching experience and he was familiar with the use of KF. The students were introduced to the KF online platform for discussion at the start of the year.

## Lessons

As shown in Figure 4, a total of 11 lessons (around 7.5 hours in total) were conducted for this study. Three KF views were created by the teacher for online discussions. These online discussions usually lasted 10 to 15 minutes for each lesson. After students' first attempt to setup with the blinking light circuit, the teacher posted group photos of student work in KF view 1 for them to discuss what work or did not work from the experiment. Students continued their discussion in KF view 1 and 2 in subsequent lessons to further explore their setup improvements and to probe deeper into the science concepts. After the final attempt, KF view 3 was setup to allow them to post rise above notes to synthesise their ideas. The teacher conducted regular whole-class discussions with the students to talk about their ideas. He used analytics feedback to support two discussions - after the students' initial KF discussion and when consolidating their learning. For the other discussions, he put up drawings or photos of students' setup or their notes from KF to guide discussion.

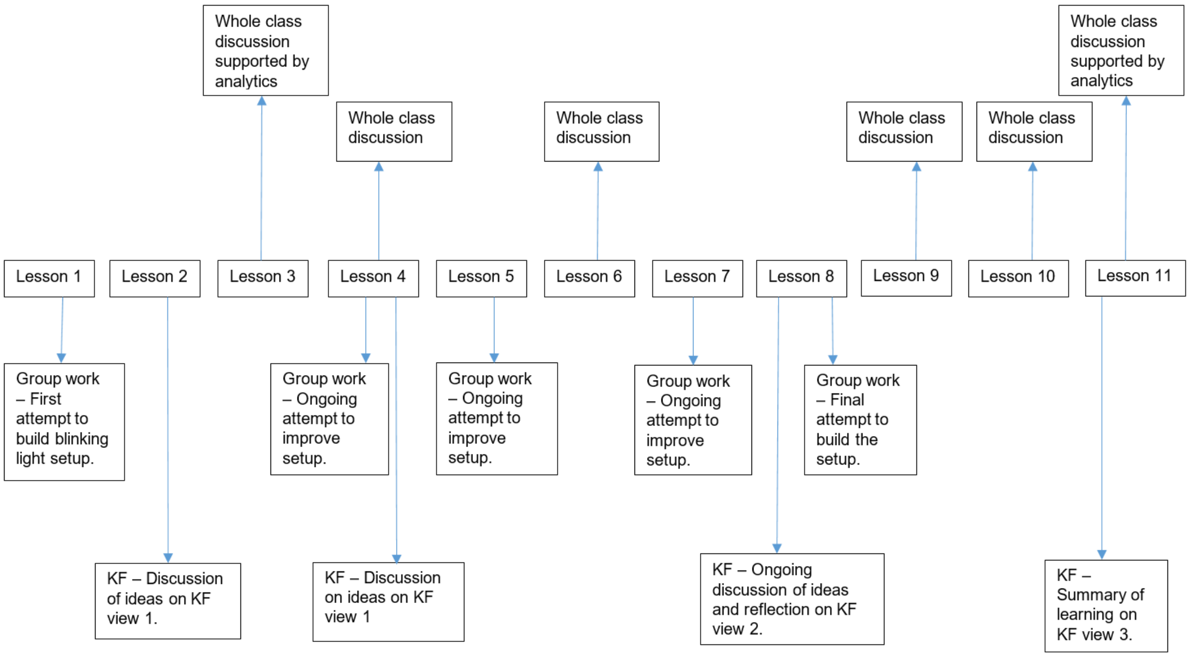


Figure 4. Flow of lesson activities and KF sessions.

## Data collection and analysis

We video-recorded all the lessons and collected records of students' notes from the KF. We also interviewed the teacher and 9 students to find out their perceptions of the learning. Table 1 shows the data collected and our analytical approach.

Table 1. Analysis of data

| Research questions | Data | Analysis |
| --- | --- | --- |
| RQ1 | • Student notes from 3 KF views | • Analysis of inquiry threads from students' KF discourse. |
| RQ2 | • 11 lessons (video-recorded)<br>• 9 student interviews<br>• 1 teacher interview | • Analysis on teacher's use of LA from lesson videos (transcripts).<br>• Analysis on teacher's and students' perceptions of LA from interviews. |

To answer our first research question, we conducted threads analysis on the students' notes in their online discourse and coded for the theory-building moves in their threads. We used the coding scheme of theory-building moves from Lin and Chan's work (2018a) (Table 2). This coding enabled us to study whether the student build-ons were extending the inquiry of topic and deepening their understanding.

Table 2. Theory building moves adapted from Lin and Chan (2018a, p.573)

| Category | Description |
| --- | --- |
| Initiate inquiry (Fact-seeking) | Initiates a thread with fact-seeking question or a statement |
| Initiate inquiry (Explanation-seeking) | Initiates a thread with explanation-seeking question |

| | |
|---|---|
| Explanation | Provides general and intuitive reasons for questions or the phenomena using simple statements or paraphrases information |
| Explanation (Deepening) | Constructs elaborated responses to theorize and to explain; conjecturing mechanisms for phenomena, incorporating new information |
| Sustain inquiry | Asks simple or superficial questions to continue the discussion |
| Sustain inquiry (Deepening) | Sustains the inquiry with deepening questions; engages in progressive problem solving |
| Cognitive conflict | Shows disagreement to other ideas; Refutes different viewpoints |

To answer our second research question, we examined lesson videos and transcripts to find out how the teacher used the CiA feedback to help students in idea improvement from the online discourse. We first identified lesson segments involving teacher-students talk with CiA visuals and then analysed the teacher's talk moves and students' responses. We adopted the Initiate-Response-Follow Up framework (Nassaji & Wells, 2000) to assess the teacher's follow up moves such as to: evaluate a student answer; provide an explanation, prompt students for elaboration or justification on an idea; prompt students to generate another idea; and to prompt students to connect with another idea. We further analysed teachers' and students' interview transcripts to understand their respective' views on the use of the CiA feedback.

<u>Findings</u>

Research question 1: How did students contribute to the discussions to support idea improvement?

Our analyses suggest that students collectively questioned and build-on their ideas to deepen the science understanding as they engaged in the ongoing online discussions. From KF view 1, we coded 7 threads from the discussion (Figure 5) where students explained why their setup worked or did not work and improved their ideas. Student build-ons in the threads were mainly explanations to describe parts of the setup and brief understanding of the connections.

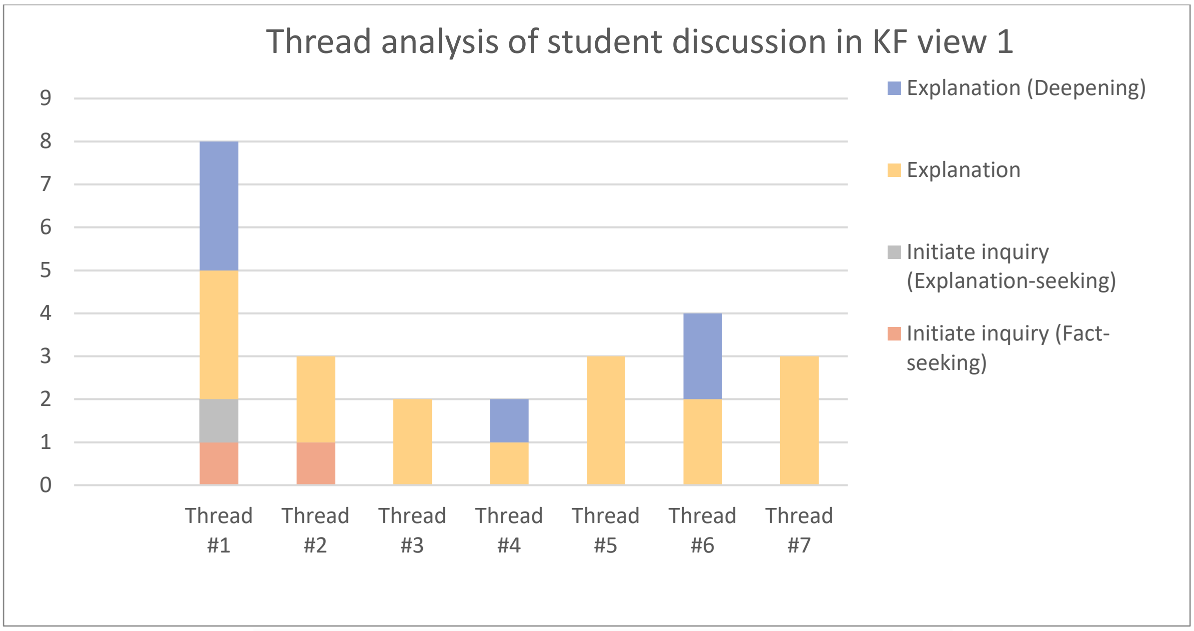


Figure 5. Analysis of students notes in KF view 1.

However, we noted some threads (see Thread 6, Figure 6) that students posted explanations to deepen their peers' ideas. Table 3 shows the analysis of student ideas which potentially stimulated a deeper understanding of the metal pole and the electromagnet. In note [1] which was a group post, students tried to explain the concept of an automatic switch by relating to the attraction between the metal pole (bridge) and the electromagnet. This explanation elaborated on how the metal pole works like a switch and the function of the electromagnet. The build-ons from S1 and S2 helped to clarify the movement of the pole [note 2 and 3]. However, the note from S3 helped them to further think about the strength of the electromagnet and the battery placement in the circuit [see note 4], an idea helped them connect to series and parallel concept.

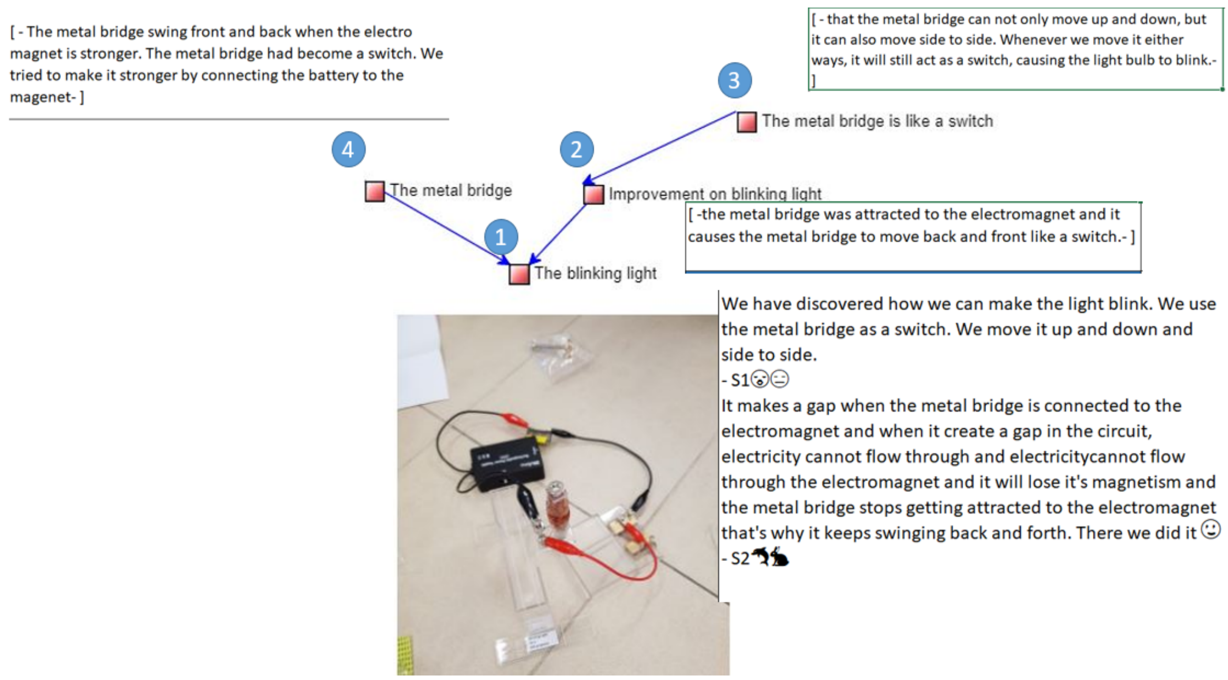

Figure 6. Students' build ons in thread #6 in KF view 1.

Table 3. Analysis of student notes in thread #6 in KF view 1.

| Note | Authors | Content | Ways of contributing |
|---|---|---|---|
| 1 | Group | We have discovered how we can make the light blink. We use the metal bridge as a switch. We move it up and down and side to side. [Student name] It makes a gap when the metal bridge is connected to the electromagnet and when it create a gap in the circuit, electricity cannot flow through and electricity cannot flow through the electromagnet and it will lose it's magnetism and the metal bridge stops getting attrating to the electromagnet that's why it keeps swinging back and forth. There we did it [Student name] | Explanation (deepening) – explaining metal bridge as a "switch" |
| 2 | S1 | New information - the metal bridge was attracted to the electromagnet and it causes the metal bridge to move back and front like a switch. - | Explanation – building on the "switch" idea |
| 3 | S2 | My idea is - that the metal bridge can not only move up and down, but it can also move side to side. Whenever we move it either ways, it will still act as a switch, causing the light bulb to blink. - | Explanation – building on the "switch" idea |
| 4 | S3 | My idea is - The metal bridge swing front and back when the electro magnet is stronger. The metal bridge had become a switch. We tried to make it stronger by connecting the battery to the magenet - | Explanation (deepening) – deepening "switch" idea in relating to electromagnet and battery |

In KF view 2, students continued to post questions and explanations on why their setup worked or did not work. We coded 16 threads from this view (Figure 6) and the analyses reflected more questions from students to deepen their understanding of the mechanism behind the blinking light setup.

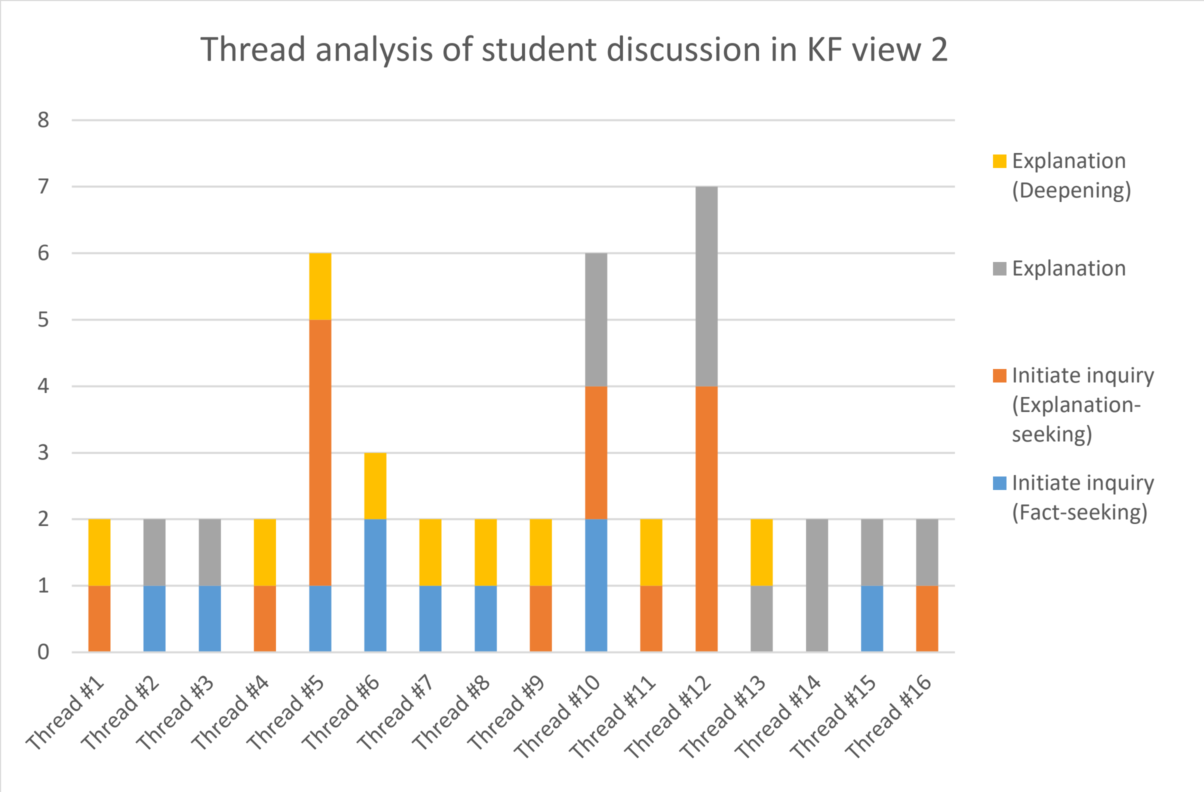


Figure 7. Analysis of student notes in KF view 2.

Specifically, students build on their friends' notes with more explanation-seeking questions to find out more about the blinking light mechanism. An example is illustrated in Thread 12 (Figure 8). In this thread, students built on their ideas to inquire deeper into the use of the sticker in the circuit. Table 4 shows our analysis of the student ideas. Note [1] showed a student idea of the blinking light which reflected a simple understanding – that there was an insulator in the circuit. The note [2] built on with an explanation-seeking question where S2 attempted to inquire about the idea. S3 (Note 3) explained that the insulator was the sticker, but S4 (Note 4) continued to inquire about how the insulator worked in the circuit. Similarly, S5 built on the idea to explain that insulator meant a poor conductor of electricity, but S6 and S7 persisted with the questions on how the insulator made the light blink. Their notes show that students started to question the deeper mechanism of insulation and electric flow by collaborating with their peers.

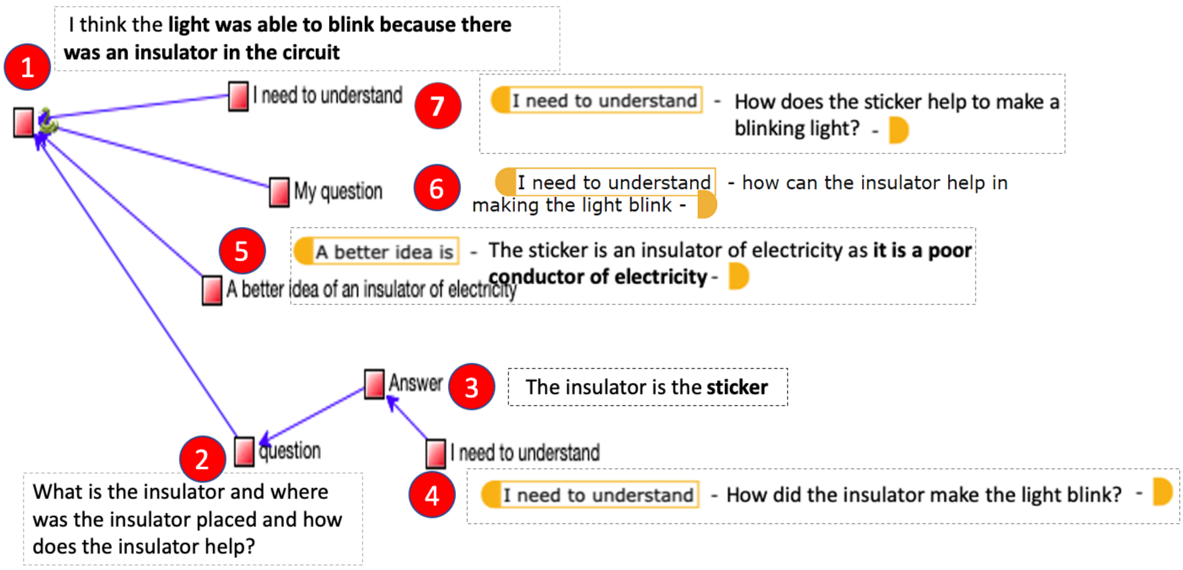


Figure 8. Students' build ons in thread #12 in KF view 2.

Table 4. Analysis of student notes in thread #12 in KF view 2.

| Title | Authors | Content | Ways of contributing |
|---|---|---|---|
| 1 | S1 | i think the light was able to blink because there was an insulator in the circuit | Explanation – "insulator" idea |
| 2 | S2 | What is the insulator and where was the insulator placed and how does the insulator help the light to blink? | Initiate Inquiry (Explanation-seeking) – how "insulator" works |
| 3 | S3 | The insular is the sticker | Explanation – state "insulator" object |
| 4 | S4 | I need to understand - How did the insulator make the light blink? - | Initiate Inquiry (Explanation-seeking) – how "insulator" works" |
| 5 | S5 | A better idea is - **The sticker is an insulator of electricity as it is a poor conductor of electricity.** - | Explanation – define "insulator" |
| 6 | S6 | I need to understand - How does the sticker help to make a blinking light? - | Initiate Inquiry (Explanation-seeking) – how "insulator" works" |
| 7 | S7 | I need to understand - how can the insulator help in making the light blink - | Initiate Inquiry (Explanation-seeking) – how "insulator" works" |

KF view 3 were meant for students to post in their "rise above" notes to synthesise what they learnt. Although we did not find threads on student build-ons, we noted efforts from students to explain and connect various concepts learnt from the blinking light activity. Figure 9 showed how a student summarised key ideas by synthesising her own ideas of the electromagnet with her friends' ideas of the insulator and parallel circuit from the online discussion.

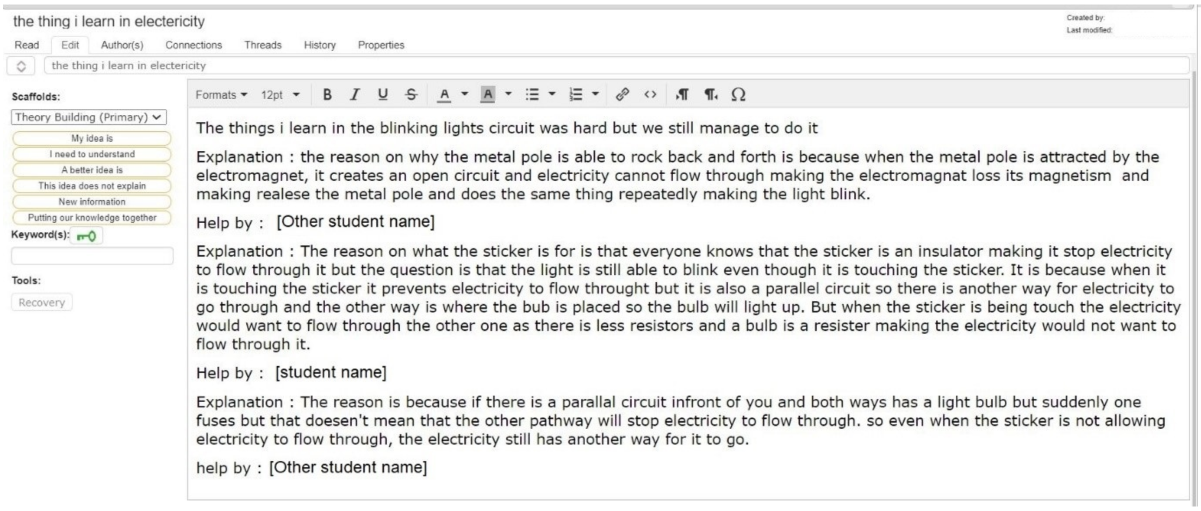

Figure 9. Rise above note from a Student in KF view 3

Research question 2: How did the teacher utilise the CiA to support students in idea improvement and what were the teacher's and students' perceptions about the analytics support?

Analyses of lesson videos reflected whole class discussion by the teacher using the analytics to (i) facilitate conceptual understanding and (ii) connect with curriculum keywords for students' idea-building. We examine the teacher's talk moves with the following two episodes. Table 5 shows an episode where the teacher used the CiA visual (Figure 10) to guide students' conceptual understanding. The visual compared student notes from KF view 1 with keywords on the topic in a primary curriculum. The teacher attempted to help students generate conceptual understanding from curriculum keywords using the CiA. In turn 16, the teacher invited students to reflect on their conceptual understanding from the ideas in the wordcloud. The orange words are the student ideas that overlap with key curriculum ideas in the primary syllabus. The teacher started with responding to a student response in turn 21 and provided prompts to clarify the student idea. He then continued to prompt students to generate different understanding from a keyword list, as shown in turn 31, 33 and 35. In turn 41, the teacher explained to students that they could deepen conceptual understanding by selecting words from the analytics to read further or connect to other ideas. The teacher was using the analytics as a thinking tool to help students form important science understanding from their ideas. In this way, students connected deeper with curriculum ideas and reflected on their knowledge gaps on the topic.

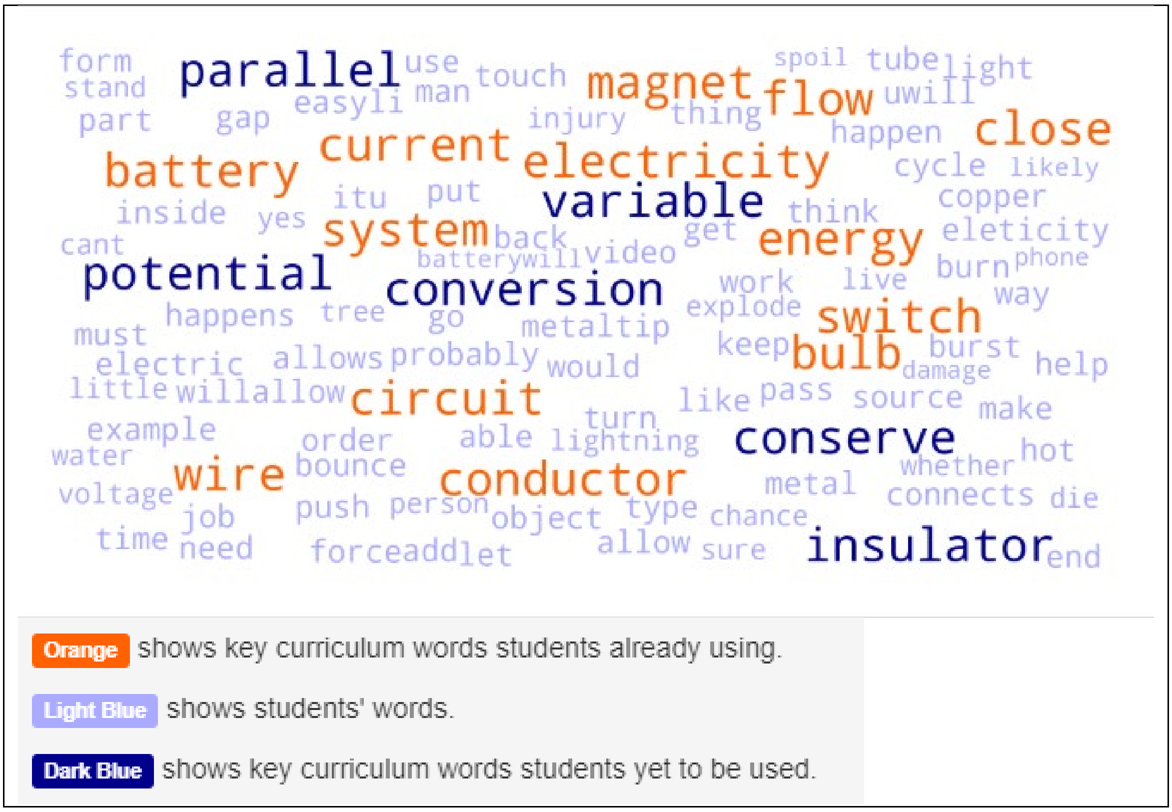


Figure 10. CiA visual comparing student ideas from KF view 1 with the primary curriculum.

Table 5. Teacher facilitation using analytics for concept understanding.

| Turn | Speaker | Content | Discourse move |
|---|---|---|---|
| 16 | T | [Refering to the visual from Figure 7]… I want you to be able to come up with a statement or a sentence using any words that is in orange… You can use more than one word, one, that is related to concepts in electricity. | I - elicit ideas |
| : | | | |
| 21 | S1 | Without a battery, it will not be a circuit. | R – student idea 1 |
| 22 | T | Let's work on what [S1] is trying to say. [S1] what are you trying to say? Full sentence. | F – clarify response |
| 23 | S1 | It will not be completed without a battery. | R – rephrase idea 1 |
| 24 | T | It will not be completed without a battery. What do you mean will not be completed? | F – restate and clarify response |
| 25 | S1 | It will be an open circuit if there is no battery. | R – rephrase idea 1 |
| 26 | T | It will be an open circuit if there is no battery? Okay … the way you explain it in a sentence must be… such that everyone can understand. Okay? | F – restate and acknowledge response |
| : | | | |
| 30 | T | Anyone wants to try? … [S2] you try? | I – invite ideas |
| 31 | S2 | A closed circuit is when there is no gaps in the circuit. | R – student idea 2 |
| 32 | T | A closed circuit is when there is no gaps in the circuit. Ok… Yes [S3]? | F – restate idea and inivte new idea |

| | | | |
|---|---|---|---|
| 33 | S3 | A battery is an energy source. | R – science idea 3 |
| 34 | T | A battery is an energy source. Okay, very good. Now, [S3]? | F – restate and invite new idea |
| 35 | S4 | [inaudible] (electrical system) | R – student idea 4 |
| 36 | T | Very good. An electrical system. She said the bulb, the battery, the wire and the switch need to work together to form an electrical system. | F – restate and acknowledge idea |
| 37 | T | But now so far what [S2], [S1], [S4] shared with us are 3 different concepts, do you realise that? Using same words, but 3 different concepts. Okay now let's move on with more concepts.[S4], [S5] do you have anything to add? | F – summarize key point and invite new idea |
| : | | | |
| 39 | T | Yes, [S5]? Can, you can use the same words. | I – initate new idea |
| 40 | S | [can't hear] | R |
| 41 | T | Okay never mind, she expanded on what [S2] said. The bulb, the battery, the wire the switch need to be connected to form a closed circuit. … She expanded on the same concept, that's ok still. | F – summarise key point |

Table 6 shows the second episode on how the teacher used analytics to connect students' idea-building to curriculum keywords. In this episode, he showed analytics (see Figure 10) and asked: "what did you all notice at first?". By doing so, he allowed students to generate various student ideas about the blinking light. In turn 5 and 7, he guided the students to review and build-on their idea by asking "What was your assumption…?" and "… what did you do". In turn 9, he helped students make connection between the word variable to their ideas by prompting "she uses words such electromagnet, battery, paper clip and bulb, what do think are those things she described?" Instead of introducing variables, he moved students from the lay-man term of 'objects' to "variables" (turn 11). Thus, these moves reflected the teacher's continual effort to carry students' ideas forward and to help them continue the topic inquiry. To help students move their inquiry forward, he ended with the phrase "you all are scientists, you are all changing variables…" to set the context for their next tasks.

Table 6. Teacher IRF talk facilitation with CiA to introduce the keyword variable.

| Turn | Speaker | Content | Discourse move |
|---|---|---|---|
| 6 | T | [Referring to the visual from CiA from Figure 7]…There is a blue word up there, actually we have been thinking about it… Can … someone in your group just quickly share with us, what is the process that you all did today. What did you all do in your groups and stuff, What happened at first? What did you all noticed at first? | I – initiate for student ideas |
| | : | | |
| 12 | S2 | When we on the battery, the lamp would light up. But then (it didn't like blinking) | R – initial response |
| 13 | T | So what was your assumption because of that? | F – prompting for justification |
| 14 | S2 | We thought that the electromagnet wasn't working | R – relating to electromagnet |

| | | | |
|---|---|---|---|
| 15 | T | So after that what did you all do? | F – prompt for elaboration |
| 16 | S2 | So we, to test the electromagnet, we removed the bulb then we took out the battery…The electromagnet attracted some, attracted the materials to the ( ). | R – elaborating on electromagnet |
| 17 | T | Okay very good… she mentioned words such as electromagnets, paper clips. She mentioned about the battery, the bulb, what are all those things that she described? | F – prompt for keyword |
| 18 | S3 | [Objects] | R – mention a word "object" |
| 19 | T | They are objects? Yes they are objects. Correct. But in terms of the experiment, what are they? Do they affect the experiment? You (don't expect them) to affect the experiment? So what are those items actually? The science word we use for it. | F – prompt for connection |
| 20 | S | [unintelligible] | |
| 21 | T | Factors.What are those things called? What did you say, S4? | |
| 22 | S4 | Variables. | R – mention a word "parallel" |
| 23 | T | Variable… so you do realise… that things that are affecting the experiment are variables…. you all are being scientists… you all are changing the variables to be able to do your experiment, and you are testing those variables… I want you think through… how do you get your circuit, your light to flick or blink, which variable is it that you want to keep, which variable do you want to change to ensure that your light will blink. And think about the variables that will affect your experiment. Alright?... | F – prompt for connection and improvement based on keyword "variable" |

Interview report showed that the teacher's interpretation of the CiA aligned with his pedagogical moves. He said that the CiA served as "a good prompt for their thinking" to "recall what they have done" or "this word is something I need to know, but I do not know". He further described the CiA as a way to "show the girls that you are on the right track" and to "show them that actually all these words are what you are supposed to know with regards to what you need to know for the science curriculum for primary school, for primary five." Consequently, the teacher facilitation using CiA appeared to focus more on helping students deepen their understanding through building on their inquiry from the curriculum keywords. For example, the teacher selected curriculum keywords like "variable" with the intention to support syllabus learning. This finding corroborated with the teacher's reports from post-lesson meetings, as shown in the following quotes:

> "so far they have not thought about the experiment as variables yet, they are still thinking of it as just different parts… they have not thought about how each variable can affect the experiment… So now as I see the CiA, I know which part to focus on already… and which is still align to allowing them to continue with the process"

> "… to re-emphasise they are learning what they are supposed to learn for the words that highlighted in orange, I got each girl to give me a sentence to explain

> what they understand by it. By doing so, I am able… to check so far whether they are at where I need them to be…"

The interview also reflected challenges faced by the teacher to facilitate the learning in a more student-driven way. He said, "So if you cannot help each other to improve your ideas, then the teacher has got to step in. which is why I stepped in, basically. So I want them to reach a level where they can do it with minimal intervention by me." He felt that his students can be more "inquisitive" as he noted that "not every member were active members". When commenting on the quality of student discourse, he said "we haven't reached the level where they can actually criticize… or they can analyse and criticize their friends' posts yet." Thus, to improve on student engagement, the teacher felt that he needed to "step in" to guide them.

Student interviews showed positive perceptions about the analytics feedback. They reported that the curriculum keywords from CiA helped in idea generation. For instance, one student said, "… when I look at those clouds I think in my mindset those clouds are actually a boost to your sentence… you can totally just make up a question immediately." They also described using the CiA feedback to find out more about science ideas they are interested in. For example, they looked up curriculum keywords such as "energy" and "resistors" from CiA to build on their understanding, as illustrated from the following quotes:

> "I actually looked up on energy. Because I don't understand what does the energy do anything, but when I looked it up for bulb in a circuit, maybe it comes up with a, from battery, it comes out with a battery then I started thinking why battery…"

> "At first I didn't know what resistors was so I tried to research it so when I saw what the, one of the resistors was, I understand why, why the circuit was going so slow."

> "… all of these hard words make me improve in my Science better. And the words that we don't really use in our worksheet or our KB right we can use these words and if we don't know the meaning we can search it online and make it in our sentence."

<u>Discussion</u>

Our findings show that engaging elementary students in collective idea improvement promote opportunities for deeper student inquiry (Lin & Chan, 2018a; 2018b; Tao & Zhang, 2018). Students' online KB discourse show that students elaborated explanations to deepen their collective understanding of concepts including closed/open circuits, electromagnet and automatic switch as they engaged in idea building in KF. They also built on with *explanation-seeking* questions to explore the mechanism behind the sticker in the setup. These findings suggest the effectiveness of a principle-based lesson design to promote collaborative inquiry, an assertion that is also supported by other works on principle-based pedagogical designs for sustained KB (e.g. Zhang, Hong, Scardamalia, Teo, & Morley, 2011). In this study, we focused on the KB principles of community knowledge and idea improvement, thus giving every students the opportunity to post their ideas in KF and to view each other's ideas as improvable. This design approach may have encouraged them to pose more questions to build on the understanding rather than to evaluate their peers' responses. Notably, students' use of the CiA supported their inquiry on the science ideas as evident from their self-reports. We found that the students interpreted the CiA feedback as a thinking scaffold for generating new areas of inquiry to learn on their own. For instance, the quote from the student who attempted to find out the relationship between curriculum keywords such as "battery" and "energy" suggests the potential of CiA to support student inquiry. While more work is needed to validate our claim, we posit that the CiA, when used in a student-centric way, can be a powerful tool to motivate student learning and to help them engage further in exploring and developing their ideas (Zhang et al., 2018).

Findings from our study also offer some insights on how the teacher interpreted and used the CiA to support collaborative inquiry. The just-in-time CiA feedback appeared to open up class talk for diverse student ideas and to give the teacher more opportunities to discuss student ideas. The teacher's pedagogical moves such as inviting students to select curriculum keywords of their choice and prompting them to articulate their own understanding represent a first step the teacher can position himself as an 'enablers of talk for thinking' (Bansal, 2018). From our analyses, we further note that the extended IRF is a necessary transitional talk pattern for developing KB teachers to foster whole-class discussion with analytics feedback to expand on student ideas. This assertion is also supported by research on classroom discourse arguing for IRF as a talk strategy to open up the dialogue for students to generate questions and to engage them in a continual process of co-construction of knowledge (Mercer, Dawes & Staarman, 2009). Given that teachers are constantly being mindful about students' agency, more work is warranted to understand how such talk patterns can transit into the discourse in KB classrooms. Furthermore, research is needed to explore teachers' interpretation of analytics tools which is a key factor in influencing the way they used it (Wise, 2014). In this study, we found that the teacher interpreted the CiA mainly as a tool to help students in covering curriculum knowledge. Consequently, he focused the class discussion with CiA to build on curriculum keywords as shown from the episode to introduce "variable" to expand the students' science understanding. Finally, a limitation in this study was the lack of understanding of students' collaborative inquiry from their face-to-face discussions. Students were also engaged in face-to-face group discussions while working on their setup. Hence, this may constitute a rich area for further exploration in subsequent work.

## Conclusion

In this paper, we showed how a teacher enacted a KB approach with KF and LA in a primary science classroom. Using KB principles of community knowledge and idea improvement, we provided a lesson design with KF and CiA to support the elementary students to collectively question and deepen their ideas on electricity. Our study showed that the students engaged in KF to collectively improve on their ideas with *explanation-seeking* questions and explanations to build on their understanding. Our findings also suggest the potential of the CiA to support the teacher and students to utilise curriculum keywords to deepen the scientific understanding. Notably, the analytics visualisations created a more open culture in whole-class talk facilitation in which the teacher and students have equal access to the trajectory of ideas and questions. Students are presented with the tool (CiA) to explore new vocabulary or ideas that are of interest to them. These early findings warrant more work to further investigate the role of CiA in collaborative inquiry, particularly to understand teachers and students' interpretation and use of curriculum-ideas analytics to support idea improvement. Our case findings are limited to a teacher and his primary science class and not generalisable across contexts, nevertheless, insights derived from the study can inform professional development to support teachers in enacting authentic inquiry practices in science classrooms.

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