Visual representation construction for collective reasoning in elementary science classrooms

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Introduction

- Visual representations (VRs) can help scientists reason, communicate, solve problems and develop the body of science knowledge further (Lynch, 2006).
- VRs are not just an aid to linguistic communication but a critical means to raise scientific problems, develop and use scientific models, participate in arguments, organize explanations, and communicate scientific ideas in all scientific processes (Evagorou, Erduran, & Mäntlyl, 2015).

Visualization as a cognitive tool

- Distributed cognition theory explains that cognition can be distributed across the cognitive system during complex cognitive activities in the surroundings (Hutchins, 1995, 2014; Salomon, 1993; Sutton, 2006).
- When students are drawing to explain something or use drawing as a medium of communication with peers, the cognition in the learning system is distributed among students' minds and bodies, constructing actions of visualization, visual representations, devices and physical environment, and social environment and interaction.

Visualization as social interaction

- Sociocultural theory of cognitive development explains that all the higher-level cognitive functions develop in an interpsychological plane first and in an intrapsychological plane later (Vygotsky, 1978).
- Like language, visualization intersects and creates meanings and vice versa through classroom interactions (Herman, 2006). It formulates one's thoughts and one's thoughts is formulated and communicated through visualization (Brooks, 2009)

Research questions

We strive to explore how VR construction takes place and how they become cognitive and dialogical tools in whole classroom talks by looking into classroom interactions through VRs.

- **What interactions occur in teacher-centered or students-centered VRs construction?**
- **How do classroom interactions through VRs facilitate students' scientific reasoning?**

Research Process

Classroom video selection

- Videos from two Grade 5-6 science classrooms in Western Canada
- No specific pedagogical interventions applied
- Extract all the scenes that VR construction occurred. (10 clips total)

Pilot analysis

- Select one short video clip of drawing
- To fine-tune the perspectives of researchers
- To determine the focus of the analysis

In-depth analysis

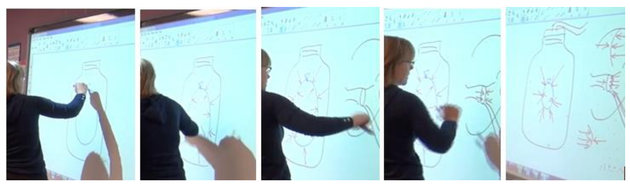
- Select two video cases of most active VR construction
- Videos were transcribed and watched repeatedly
- In-depth discussions and cross-analysis led to consensus on the themes.

Findings

CASE 1. Air Pressure and Weather Device

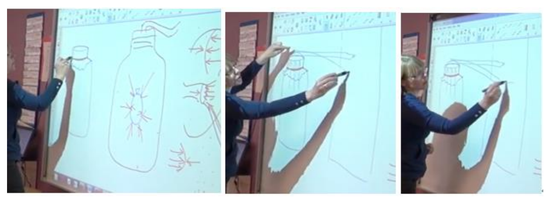
Theme 1. Arrows: symbolic visualization of abstract concepts

A student, Thomas' verbalized experiences are visualized through the teacher's drawing on the board. The teacher changes the numbers, sizes, and directions of arrows to visualize air pressure around a jar and balloon. Between the students and the teacher, there is a common ground of understanding this symbolic tool to continue meaning-making together.



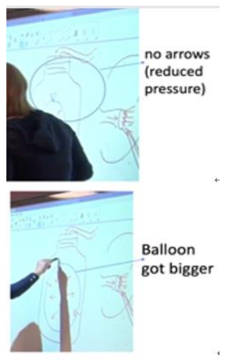
Theme 2. Three drawings on the board: Visible connection of knowledge

While the teacher is visualizing Thomas's ideas, she is explaining how air pressure works in the bottle. Then she is drawing an eardrum to recall students' knowledge from the previous lessons and also their experiences in everyday lives. Then the teacher attempts to connect this idea to the activity she has prepared for the next class. Now all of the three drawings are side by side, showing how those ideas are connected around air pressure.



Theme 3. Teacher-centered visualization and guided reasoning

In teacher-led classroom interactions, the teacher's drawing became a tool to make one student's idea open to the whole class, inviting others to think together on the topic. Seemingly, the author of drawing is the teacher in this episode, yet, the agent of thinking to develop the drawing is from both the students and teacher in the collective community of classroom dialogue.

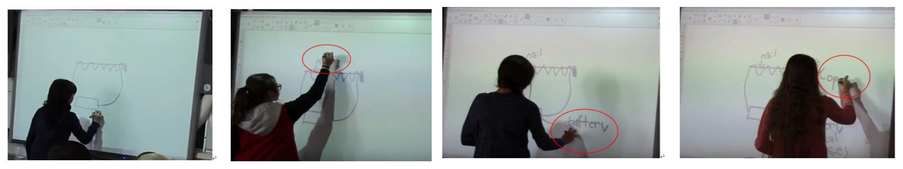


Teacher	*Let's imagine that I, uh, take away some of the air pressure .. Inside the jar, okay? So I'm removing some of the air pressure. Ooh, what is going to – is the pressure on the balloon and outside of the balloon even now ?*
All	*No*
Teacher	*So what is going to happen to the size of the balloon? Yeah?*
Cathy	*Two things: you can use a vacuum and like for the tube you can use a vacuum. And ...*
Teacher	*So I can suck air out, so there's less – (removing arrows around the balloon)*
Cathy	*And second of all, kaboom!*
Teacher	*Air out here. So the balloon will do what? Will it get bigger or smaller?*
Cathy	*Bigger.*
Eden	*Kaboom*
Teacher	*So it got bigger, right? (erasing and redrawing the balloon around the arrows) Because there's more pressure on the inside now, so now my balloon is going to become larger, –*
Eden	*And then it can't hold all the air so then it'll explode.*

CASE 2. Electromagnet

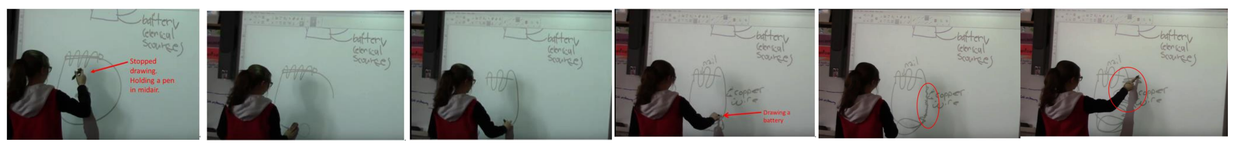
Theme 1. Image of electromagnet: Common ground for reasoning

Four students came to the board, one by one, to draw the image of the electromagnet. The first student drew the general image and the next student added or revised one or two things. This shared image provided a common ground for students to develop their reasoning, ask questions, and explain their thoughts.



Theme 2. Reasoning through drawing

Students used an act of drawing to explain ideas or to enhance arguments. During the discussion, if a student felt that it was not enough to explain in words, she came forward to the smartboard and drew the image to explain further.

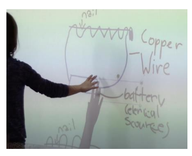


Rae drew the electromagnet, stopped, erased it and drew the new one with the labels, stopped again, then started her explanation with drawing the lemon, the battery, and small and big waves to indicate the strength of the electric current. While she stopped drawing and watched the image, it indicated that she was thinking.

Theme 3. Students centered visualization and shared reasoning

There was an active discussion among the students, and the teacher facilitated the discussion. Students reasoned and developed the ideas together and drawings were in the center of their discussion.

Rae, as shown above, went to the smartboard and began to draw and explain her thoughts. When Rae explained about the battery and lemon, the teacher asked the class if they could make the electromagnet with the lemon. Amy and Eve suggested their explanations about why they cannot make an electromagnet using the lemon, saying that the lemon was not an energy source. Then Iris stood up and went to the board and scroll up the screen to get the first drawing of electromagnet and started to explain and scrolled down to the second drawing drawn by Rae.



Iris — *I don't, wait, excuse me, I don't think it would work because if you get this circuit, um, most of the people that got their thing to work they had two batteries and I think the only group that was successful doing it with one battery was Evelyn's group and they had, they could only pick up graph paper and things like it was very low magnet*

Iris — *I don't think it would work…… A battery can charge say like-like a hundred increment size and …..a lemon could possibly really charge anything, well very small things, so I don't think we create any electromagnet because it was too hard for a single battery to charge.*

Discussion & Implication

- Students were actively engaged in both teacher-centered and student-centered visualization construction. During teacher-centered visualization, students participated in drawing verbally, providing feedback, interpretation and explanation on what the teacher drew on the board. During the student-centered visualization, students took turns to collectively drew a drawing on the board to explain their thoughts.
- In both cases, visualization was at the center of their conversation and meaning-making. Drawing became part of their cognition and reasoning process.
- In visualization construction, there was a certain level of common ground understandings of drawings among the teacher and students such as symbols or models, which made reasoning and knowledge building collective. Based on these common grounds of drawings, students and teachers developed their meaning making and communication together. Visualization as cognitive tool develops in social realms.
- Teachers' prompting questions and comments were also critical to develop students' reasoning through visualization. Teacher scaffolding strategies on collective visual construction need to be further researched.