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Studying the Water Cycle

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REFLECTIVE RECONSTRUCTION OF VISUAL PRODUCTS: STUDYING THE WATER CYCLE

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ABSTRACT. This paper presents an argument about the cultural construction of visual products. Based on data from video observations, interviews and the collection of student-produced (visual) artifacts, a material ethnography approach is presented. Applying reflexivity with the use of visuals, the following argument is made. Instead of revealing insights through just one approach, a reflective methodology should consider: (a) the context in which the visual was produced; (b) the content of the visual; (c) the contexts in, and subjectivities through, which visuals are viewed; and (d) the materiality and agency of visuals. A case of a New Zealand year 7/8 primary science class studying the water cycle is presented. It is argued that teaching science concepts like the water cycle through visualizations cannot be an abstract endeavor because even when abstract ideas are presented, they are visualized as concrete objects. The teacher used a range of visual materials including video clips, diagrams, student drawings, and student produced 3D models, each endowed with unique material and visual dimensions. The teacher activated those through talking, writing, drawing and working with artifacts and purposefully recorded conversations with individual students to be able to reflect on and track the children's progression in understanding.

Keywords: visibility; material objects; reflexivity; subjectivity; objective; cultural constructions

Introduction

This article presents an argument about the cultural construction of visual products in a science classroom. The production of visual materials and artifacts including videos and three dimensional models is a particular cultural practice in science and can be witnessed in many science classes. Visual depictions have historically been amongst the ways for science to communicate, represent, teach or learn about the complexity of the natural world, yet not necessarily with the intent to be objective

but instead, to shape ideas about things (Daston & Galison, 2007). Daston (2004) explains that since the middle of the sixteenth century, scientists have used and produced visualizations of nature that would fit their written descriptions. For example, it hasn't been uncommon that visual illustrations were produced based on the close examination of several artifacts of the same kind to compose a depiction that would perfectly portray all the key aspects to be communicated. Hence imagery in science has been traditionally attached to a specific meaning that is intended to be interpreted in a particular way.

In her book on technology, literacy and learning, Carey Jewitt (2001) explains that multimodality and the unpacking of different semiotic resources we may be utilizing to understand things is a helpful way to identify the grammar of a set of resources (p. 17). This approach takes not only note of the product but also of the social process that produced the product. "Understanding how the visual both produces and represents culture is the reason attending to the visual forms of representation" (Jewitt, 2008, p. 9). From this perspective material objects in science are regarded as communication modes that come with different affordances and may also include embodied expressions and gestures (e.g. Kress, Jewitt, Ogborn & Tsatsarelis, 2001).

The cultural construction and the products of visualized knowledge in science, including when visuals are used to explain one's own learning or understanding, is thus important in order to interpret the transformative potential of the visual. Science works with the visual in a very particular way, including depictions of abstract, invisible or difficult to observe phenomena. To use an example, I will draw on case data that was collected in a primary science class learning about the water cycle. The water cycle is a scientific concept that describes the processes involved when water in its different states moves between the land, the ocean, and the atmosphere. Given the significance that water plays for life on Earth, the topic is featured in all science curriculums in some way or the other. The case that is used tells of a teacher and her year 7/8 class who explored the water cycle. To do this the teacher deliberately employed a variety of visual tools in an effort to overcome the challenges when students have to learn about abstract scientific concepts. They were difficult ideas, due to materials or processes being invisible, too small, happening too fast or too slow for direct observation. Next, I continue by sharing some theoretical ideas on the significance of visualization for science education.

Visuality and Its Role in Science Education

While there is plenty of research in science education that focuses on visual representations, there has been a focus on the connections between visuals and conceptual understanding. This interest for instance, is grounded in neuroscience research that says that conceptual knowledge is visually organized through perceptual systems (Kan et al., 2010). Visualizations play a significant part in

science education to depict abstract ideas (Buckley, 2000), allowing students to 'see' things that cannot be seen, such as details of chemical processes (Kozma, Chin, Russel, & Marx 2000). However, depending on the nature of the visualization, particular skills and techniques are needed, and to use visualizations for teaching and learning purposes may require that individuals may need to adopt new learning strategies and individual schemas in order to make inferences (Halpern et al., 2015). This may include mental but also physical manipulations of visualizations such as videos that have been produced as part of the visualization process. For example, a video may zoom in or out to highlight and emphasize particular points of interest.

Prain and Tytler (2012) identify three perspectives on using representations in science: a semiotic perspective, with a focus on symbols and materials, an epistemic to show the relationship between representations and the big picture of ideas, and an epistemological perspective to identify challenges of depicting causalities. The authors argue that students draw on diverse cultural and cognitive resources which are contextualized in the topic that is under investigation. However, traditionally the focus on materials in science has been ignored or underplayed, giving rise working with material ethnographic ways to study socio-material assemblages in science education (Fenwick & Landri, 2012).

What Material Ethnography Is

That studies on science education may need to involve more than focusing on talk has been emphasized and empirically examined by a number of scholars (see for example, research advocating for the inclusion of sensory experiences Roehl, 2012). This should not however, depreciate the importance the studies on how to learn and master scientific language (Mortimer and Scott, 2003; Lemke, 1990). A focus on understanding the connections between students, their teacher and the materials they use emphasizes that science education is also about embodied human/socio – material experiences, and taking note of the complexity of the experiences made include where and how they come together and co-shape the learning experiences (Fenwick & Landri, 2012; Roehl, 2012). Taking note of the complexity of factors that come together that are orchestrated by the teacher, the students, and the materials used and produced, require a carefully tuned approach for the study of educational experiences.

Roehl (2012) presented three approaches that can be used for ethnographic studies that consider materials: Actor Network Theory (ANT), Social Construction of Technology (SCOT) and postphenomenological and pragmatist notions of materiality. Each of those three methodological research approaches identifies how to address socio-material conditions through ethnographic examinations but each methodology has its limitations. Actor Network Theory (ANT) most prominently shaped by Bruno Latour, John Law and Michel Callon, attribute as much significance to the material object as to the human actor. This creates a symmetry

since material objects are viewed as actors, thus allowing the ethnographer to examine how material objects shape and are being shaped by human actors and vice versa. This allows for the consideration of all factors (material and human) to be considered that shape social situations. If ethnographers use such an approach they can reassemble the social, as Latour put it (2005). However, Roehl critiques this approach since it does not necessarily shine enough light on transformations or creative responses to material objects. Science Technology Studies (STS) include the theoretical approaches of Social Construction of Technology (SCOT) that are interested in exploring how technology shapes human activity. As described in the seminal work of Pinch and Bijker (1987), SCOT is often used by those interested in user centered design processes, thus highlighting the social dimensions in the production of material artefacts. Postphenomenologists such as Don Ihde (2009) propose that researchers should examine the use of materials, objects and how people go about it. This gives opportunities to identify when things do not work out as planned and create situations that can only be resolved through reflexivity. It allows the researcher to examine details of situations including emotional or embodied responses, but Roehl finds that the limitation lies in its scope since it is difficult to move beyond the contextual example and make sense of wider networks.

In this ethnographic study, I am interested in visual products and their connection to learning situations. I situate myself in sociocultural perspectives (Wertsch, 1998) on learning to expand ethnographic methodologies, to pay particular attention to the visual aspect of materials and what this could mean for learning. I considered three basic conditions. The first is that visual material artifacts need mediation to come to life. As James Wertsch (1991) explains: “They have no magical power in and of themselves” (p. 119). Deliberate selections are made by teachers and students for exemplifying ideas, designing visual learning products in order to tell a relevant story, so it is about more than just use (Wenger, 1998). Visual productions become scenarios and resources of ideas and interaction (Roth, 2005; Wells, 2002).

Second, material products have both material and conceptual dimensions (Cole & Engeström, 1993). As Gordon Wells (2002) explains:

The materiality of the object is critical in allowing it to become a focus on joint activity—something that can be sensually perceived, handled and acted on. At the same time, it is the symbolic aspect of the object that allows it to participate in the students’ progressive attempts to increase their understanding of the phenomena under investigation. (p. 45) In the classroom, it is then through the teachers’ orchestration of investigating the attributes of those products, that students learn to discern the attributes of objects that provide entry points for discussion and the development of a consensus about the underpinning concepts and processes that can be a rich and powerful source of ideas and feedback (Cowie, Moreland, & Otrell-Cass, 2013).

Third, material artifacts, once produced can be revisited (Wertsch, 1998), interrogated and changed if needed, this can happen over time because they can endure in contrast to speech (Jordan & Henderson, 1995; Roth, 2005). This way they become also historical records of the past with the agency to shape future interpretations (McDonald, Le, Higgins & Podmore, 2005).

This implies that visual material products that are available to students mediate interactions and learning practices. For the classroom ethnographer who visually records and analyses episodes of such occurrences, it is then important to take note on how the teacher introduces and works with a task that involves materials to understand and make sense of how these objects shape what can be witnessed.

Understanding the Cultural Construction of Visual Products through Reflexivity

In this article, I am particularly interested in making sense of students' interactions with their science classrooms productions and the role of visual interpretation. This means that I am exploring how to best understand and reinterpret what had been visually recorded through videos during ethnographic classroom studies. The focus of the episodes of interests in the videos were instances where students were reflecting over their own visualizations of scientific concepts, through videos and 3D models. The focus here is also on addressing the researchers' challenge in being ethnographic with visual products. Sarah Pink (2007, p. 22) provides a useful description in that ethnography is not a method but a methodology that seeks to experience, interpret and represent culture and society.

As mentioned above, Prain and Tytler (2012) provide inspiration for analyzing visualizations, i.e. drawings based on the use of and availability of cultural tools. Rose (2001, 2014) emphasizes the importance of applying reflexivity in order to gain insights into: (a) the context in which the visual was produced; (b) the content of the visual; (c) the contexts in, and subjectivities through, which visuals are viewed; and (d) the materiality and agency of visuals. (Rose refers to images not visuals). This approach requires reflexivity and takes the wider context into consideration, with implications for the educational ethnographer wanting to understand interactions and materially mediated learning situations. The insights that can be gained through reflective approaches include people's personal stance and their perceptions of self and the world but this also requires that the researcher is aware of the role reflexivity plays (Savin-Baden, 2004). The four aspects for such reflective approaches are in more detail:

The context in which the visual product was constructed

Rose (2014, p. 19) also referring to Kress (2010), argues that visual communication should be considered as a design process set in a context within which the communication takes place. The context includes who is the anticipated audience,

the modes of communication and the available resources and perhaps also the origin of those resources especially if they are multimodal.

The content of the visual product

Considerations of the content should take note of what is used and depicted. Content Rose (2014) explains, is never neutral and always an interpretation of the world. She highlights that visual products need to be taken seriously by researchers, to deal with the challenge of interpretation. Rose (2014) explains that working with visual material often leads a researcher to identify content sources, drivers and barriers and interpret or overlay explanations about them that cannot be seen.

The contexts in, and subjectivities through, which visual products are viewed

The challenge with working with, and making sense of, reflexivity is that it is shaped by one's point of departure including "perceptions of self and ... perspectives of the world, which ultimately is connected to our personal stance" (Savin-Baden, 2004, p. 366). Savin-Baden points out that adoption of understanding, and working with reflexivity, has to start with situating one self. In this case it requires situating the student, the teacher and the researcher.

The materiality and agency of visuals

Visual products are 'objects that talk' (Daston, 2004), and in order to gain insight into these talking objects, it is necessary to identify what aspects have been foregrounded and emphasized by the designer of the visual product and to take note of visibility (Rose, 2014). Rose explains that visibility is about the ways our vision of things is constructed. This is also necessary to identify the cultural drivers for utilizing particular norms and ways of presenting and communicating information as well as preserve a historical snapshot thereof (Daston, 2011). Next, I will discuss the methods employed in this study.

Working with Visual Research Methods in This Case

I used video recordings and photographs, together with field notes and interview data to trace and make sense of how young people worked with their visual products in the science classroom. The way how the visual data was examined was not necessarily with the aim to present a precise truth, but to tell *a* truth (Wilder, 2011) and to consider the nature of information that can be accessed (Rose, 2014), thus taking on an archeological approach to the research investigation (Law, 2009). Exemplifying such ways of interpretation and reflection, the case of a New Zealand year 7/8 primary science class studying the water cycle is presented. Teaching science concepts like the water cycle does not necessarily need to be an abstract endeavor (Ingold, 2006, 2013; de Freitas & Palmer, 2015) despite of its inherent problematic details that lead to children's conceptions in science (Driver, Asoko, Leach, Mortimer, & Scott, 1994). I conducted ethnographic video observations

over three weeks of classroom teaching where the teacher used a range of visual materials including video clips, diagrams, student drawings, and student produced 3D models, each endowed with unique material and visual dimensions. The teacher activated those through talking, writing, drawing and working with artifacts and purposefully recorded conversations with individual students to be able to reflect on and track the children's progression in understanding. More specifically, she repeatedly asked the children to draw and then reflect on their drawing, recording their reflections so she could revisit those conversations and trace their development. The teacher also asked her students to video record reflections, such as video recording in pairs the details of the 3D model the students produced. At the end of the unit, the teacher, the researcher and a selected group of students had focused conversations about the selected drawing the children made.

I am now going to present the analysis of students' visual products. Names used in the following section are fictitious to protect the identity of the individuals. The case is presented in two acts that contextualize how the students worked through this water cycle unit. The first act explains and shows what the children had to do, the materials they used to create their visual products while the second act aims to unpack the context that shaped the conditions for such a production.

The 3D Model: A Dam and Ice-comets and How Water Got to Earth

First act – the visual story

Prolog: The students finished building their 3D model using the following materials: A plastic container, soil, plant material (leaves, grass), white straws, water, a slab of rock, gravel, coat hanger and a plastic bag. After the assemblage of the different materials into a scene, they produced a video having a discussion with each other where one boy interviewed the other about the model and its connection to the water cycle. The screenshots in figure 1 show selected scenes from the video the two boys produced. The scenes represent what the cameraman focused on and emphasized.



Figure 1 Screenshots from the video two students took explaining their 3D model.

Following is the transcript from the video the two boys produced. In it Tom takes on the role of the cameraman and interviewer while Max explains the details of their 3D model.

Tom cannot be seen, he is the cameraman, but he has a conversation with Max.

Tom: Recording...

Max: Well, that's our model. We made a dam (*touching the rock slab*). And there are some sewage pipes going back and forth (*referring to white straws*). We had to quickly ruffle the bag for clouds cause... we didn't have any time.

The water originally comes from the river. The sun comes along and it makes the water hot (*puts fingers in water*). And (.) hot steam rises. So, it rises up and forms a cloud. And after the cloud is made when it gets to a colour like this (*touches and shows the plastic bag*) it starts to get heavier and weighs down more and then it rains again. It goes on the land and gets absorbed over there in the trees (*points towards green leaves on side of model*) or... it gets into the water here (*puts finger into water*) and still lives.

Tom: Well, can you tell me the thing you told me before... that the sun got away or something?

Max: When the clouds are formed (.) the clouds come up and (.) they block out the sun (.) and... it puts too much hot on the clouds making it rise too high, so that's how they get high.

But before the water originally (was) getting to the lake is actually ...from space...ice comets, a long time ago, and hundred thousand years ago or something came ... smashing down onto Earth and the atmosphere...it was coming down the atmosphere... and it would burn up and ... exorb (*Max's formulation*) and turn into water, into liquid and then rain down and turn into a river.

Second act – reflections on the visual productions

The context in which the visual was produced

The production of the three-dimensional models and the filmmaking occurred in the classroom. Science classrooms are places of multimodal learning, where speech, writing, images, gestures, materials and three-dimensional models shape the ecology of learning (Jewitt, Kress, Ogborn, & Tsatsarelis, 2001). However, classrooms are also spaces that represent institutions and their expectations. Foucault (1991) talks here about governmentality to highlight that these places are signified by power structures, intentionality and control. Schools are not value free and dictate certain societal expectations. For science education, it means that particular ways of seeing and interpreting the world are emphasized. Everyday experiences that are acceptable elsewhere can be rendered incorrect or unscientific in the science classroom.

In this case, the teacher had planned the activity relatively early in the teaching unit. The excerpt here from her teaching plan shows her plans and also her reflections on why an activity was planned and how things went (in colour).

Micro Task	Focal Artefacts <i>Any resources/tools you/the students may use</i>	Skills/time required to complete task	Planned Interactions	Intended Learning Outcomes
<i>Number micro tasks</i>	<i>(Identify type of artefact to highlight what support may be needed in using the artefact/tool)</i>	<i>(Identify what you know about your students ability to complete the tasks set with the planned artefacts and consider the time needed)</i>	<i>(Identify here how you think your students will engage with the artefact/task)</i>	<i>(What do you expect students to gain from this task, and how you will assess this include here also any assessment – formative/summative)</i>
A 1. Brainstorm where water comes from and goes to.		Prior knowledge – students may need a starting point e.g. rain	Explain the key understanding and why we are investigating water, as a topic. Key Question: Where does our water that we use come from? Students brainstorm ideas in Science Books My Life as a Raindrop Discussion as class around student ideas. • brainstorm where water comes from and goes to. Video - The Importance of Water	To evaluate their own knowledge of topic
A 2. Construct a water cycle	Equipment for constructions: Large plastic container (this might be a large plastic bottle), half a bucket of soil or potting mix, two or three wire coat hangers, large clear plastic bag or plastic wrap, pebbles and small rocks, plenty of water, some small plants, moss, ferns, grass seed or bird seed List of questions Flip videos	Prior knowledge of the cyclic nature of the water cycle Components that contribute to the water cycle	Students use equipment to construct a model of the water cycle. Students take flip video to explain their thinking behind their construction. Scaffold questions for explanation. Why are plants included in the water cycle?	The continuous movement of water on, above and below the surface of the Earth (also known as the hydrological cycle). <i>This was quite interesting. I think it helped to clarify with some students that the water does not just sit on top of the soil, but goes into it, some even put in holes.</i>

Table 1 Excerpt from the teacher's planning document.

The teacher had clear expectations such as "... the continuous movement of water on, above and below the surface of the Earth...." She also listed the materials that

should be available to the students. The closer examination of the context for the visual production, on both the model but also the video recording, reveals the circumstances on how they have been produced.

The content of the visual product

The different modalities shaped how the visual products were composed and shaped the learning content. The three-dimensional model showed a unique interpretation of the challenge; a scenario where the two boys decided on constructing a dam to produce a story of their interest. The content produced in the video reflected the discussions the two boys had before hand.

The content details included dammed water and piping (man-made interferences with the natural environment), the land and plants and their connection to the water cycle (from the recording: “.... It goes on the land and gets absorbed over there in the trees”). The visual product’s three-dimensional model and the video displayed content that carried agency and represented social practices (Rose, 2001), such as the damming of water.

The contexts in, and subjectivities through which, the visual products are viewed

The context in the video included also insight into the boys’ views on what was interesting and of significance to them, such as the origin of water on Earth (from the recording: “....But before the water originally (was) getting to the lake is actually ...from space...ice comets, a long time ago... ..it was coming down the atmosphere... and it would burn up and ... exorb (*Max’s formulation*) and turn into water, into liquid and then rain down and turn into a river.”). Here Tom reminded Max of the conversation they had before the filming. The short moment in the recording gives insights into how the two boys made meaning of the abstract concept as well as how this was further connected to information they had identified as interesting and significant. They contextualize the story in their three-dimensional model. The visual products carried unique meaning, and in that sense pushed forward the subjectivity of the two producers.

Also, the structure of their video starting with explaining the features in the model, then explaining what they interpreted as relevant for detailing the water cycle and later adding additional information, gives insight into the boys understanding on what they saw their audiences (their teacher, other students, the researcher) may expect them to produce. The children demonstrated in the way how they transformed materials also that ‘ideas are lived rather than abstract and full of personal values and judgments’ (Sullivan, 2012, p. 5, referring to the works by Bakhtin).

The materiality and agency of visuals

The materials the teacher made available to the students for constructing their visual products also included a video camera (the teacher refers to flip video in her planner, an easy to use video camera with in-built USB connector). This camera and the video it produced meant the children could quickly and easily review and

revise. The same applied to the other materials. When Max explained in the video that water heats up and evaporates, he stuck the fingers of his hand into the water of his model, sensing and performing the concept of water warming up. The materials used for the three-dimensional model were overlaid with dramatized meaning.



Figure 2 Max touching the water while saying ...
“The sun comes along and it makes the water hot.”

The assemblage of the different material components made these visual products into objects that mediated visions (Turkle, 2011). Evelyn Fox Keller (2011, p. 301) reflects that: “As scientists, our mission is to understand and explain natural phenomena, but the words *understand* and *explain* have many different meanings” (emphasis added by original author). The materials endowed with materiality were put together in such a way that they contributed to the boys’ reframing of the task at hand.

Discussion

The presentation of unpacking the visual products of the two boys also requires a reflection on the researcher’s position to understand how the kind of meaning (a truth) is produced here. This analysis is situated in a sociocultural perspective meaning that the interpretation of visual production expands on multimodality and what it means for learning and the appropriate units of analysis. Since science is full of discipline specific language, symbols and texts that scientists use to develop, represent and communicate knowledge it is important how the interpretation of signs and symbols (semiotics) are carried forward and adapted by teachers and learners. This means also that different materials and objects including drawings, three-dimensional models, are often accompanied by different actions, so are not necessarily meant as standalone entities (Cowie, Moreland & Otrell-Cass, 2013).

This way of unpacking visual products reflects also the specificity that these material objects are being viewed by various audiences (Rose (2001), in this case the students themselves, other students, the teacher, the researcher). As Sarah Pink

(2011) reflects on Paul Hocking's (1992) work, ethnographers describe events they have witnessed and this kind of work is selective and interpretive.

The argument has been that to understand the significance of visual student products in science classrooms, it is important to pay attention to how they were conceptualized, produced and purposefully presented. The explanations that accompany the productions are significant in making sense of context, content, subjectivity and materiality that make up the objects that have been produced. The visual depictions were not necessarily produced with the intent to be perfectly objective, but with the intention to introduce audiences to the boys' ideas about things (Daston, 2007).

In the context of the study the teacher applied a pedagogical approach to utilize visual products as part of the classroom learning. It also included that the teacher was able to discover her children's existing and developing knowledge and experiences. By using different visual means and media the children were able to transform their lived experiences and their stories to share their own insights. The process itself allows also for the individual to engage in a reflective process (Rose, 2011). This reflexivity is demanded for by the combination of modes: the model combined with recorded video is about being able to tell a story and expanding from what can be seen in the model to imagining the real world and mediate visions (Turkle, 2011).

Conclusion

In this article, the aim was to present the case of a visual material production during a science unit about the water cycle. I assume a socio-cultural position that the interactions that take place in science classrooms are mediated by social, material, temporal, historical, political and cultural contextual factors (Wertsch, 1998).

The ambition was to apply material ethnography with an archeological approach to the research investigation (Law, 2009). The visual products video and three-dimensional model demanded particular things from the students Max and Tom when they were used and produced. They were assembled through the teachers' orchestration, thus bestowing everyday materials with new identities (a plastic bag becomes a cloud) and the ideals and aspirations of a science curriculum. Following a Latouring argument, the productions also represented what the teachers and the boys were expected to generate in the context of being together in the science classroom. The dramatization the boys applied to those visual objects emphasized and identified the reflective processes with those ideals (Rose, 2011). This reflection process was apparent throughout the entire activity and revealed also their imaginaries and personal stories.

Returning to the matter of teaching science concepts like the water cycle this case shows that this does not necessarily need to be an abstract endeavor (Ingold, 2006, 2013; de Freitas & Palmer, 2015). Understanding the cultural conditions for

producing visuals requires a reflective cycle of interpretations by students, teacher and researcher. More than understanding young people's meaning making of the water cycle, such a process allows for a reflective reconstruction of visual materials that also describe the nature of the interrelationships between students, materials and the production of concrete thinking.

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