The Use of Visual Evidence for Planning and Argumentation

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Abstract: We report on two learning environments where students used visual evidence (digital photographs) for the scientific practices of planning and argumentation. The first is a knowledge-building environment called Neighborhood Safari, where Grade 5/6 students (n=45) construct investigation plans concerning schoolyard wildlife; the second is an immersive simulation called EvoRoom/Zydeco, where Grade 11 students (n=51) capture observational evidence to support knowledge claims. We developed coding schemes to assess support levels (ranging from 0-4) provided by textual and visual evidence concerning (respectively) students' (1) investigation plans for observing schoolyard wildlife with camera traps and (2) knowledge claims about climatic conditions in an immersive rainforest simulation. Textual evidence was found to provide greater support for the scientific practices of planning and argumentation than visual evidence. High-level visual evidence made connections to investigation plans and arguments, using (1) visual annotations (e.g., arrows), (2) comparison or contrasting images, (3) explanatory captions or (4) compositional techniques (e.g., cropping).

Keywords: science practices, visual evidence, collaborative inquiry, mobile applications

Introduction

A central assumption that underlies contemporary science education standards (e.g., NGSS Lead States, 2013) is that learning should be situated within *authentic scientific practice.* In this paper, we report on two learning environments where students used *visual evidence* (i.e., non-textual artifacts, such as photographs and drawings) to support two practices that the NGSS has deemed essential for students to learn: (1) planning and carrying out an investigation and (2) engaging in argument from evidence. Our work is situated within the theoretical tradition of classrooms as knowledge communities, where students engage in methods of knowledge construction that are in line with authentic scientific practice. As students work together as a knowledge community, a collaborative knowledge base is constructed through the sharing of data, ideas, and theories within a rich social environment (Scardamalia & Bereiter, 1999).

Inspired by this work, we are investigating our own theoretical model known as Knowledge Community and Inquiry (KCI) (Peters & Slotta, 2013). This approach situates knowledge construction within a technology-mediated environment, and scaffolds student groups as they contribute new ideas, theories, data, and information to a knowledge base, allowing the community to make directed progress towards inquiry goals. The KCI model guided the inquiry curriculum design to support knowledge building in two case studies. In the first case study, we describe an environment where students exchanged digital inquiry notes concerning their planned investigations of wildlife in their schoolyard. In the second case study, we present an immersive simulation environment where students captured and exchanged observational evidence to support scientific argumentation about climatic conditions in a tropical rainforest. The goal of these two case studies is to understand how students used *visual evidence* to support the scientific practices of planning and argumentation. In our analysis, we focus on students' use of visual evidence—in the form of digital photographs—from the community knowledge base. Specifically, we ask: Does students' use of textual evidence differ from their use of visual evidence for plans and arguments? We aim to reveal the kinds of technological and pedagogical supports that learners may need to engage in planning and argumentation when using visual evidence.

Visual evidence

As a regular part of scientific practice, scientists use both written material (e.g., text) and visual material (e.g., graphs, diagrams) to make discoveries (Coopmans et al., 2014) and communicate findings with peers and the public (Tufte, 2006). As new forms of data capture become increasingly a part of students' everyday experience (e.g., using a mobile device to take a photograph), such practices are also becoming more common in science classrooms. For example, the Zydeco platform enables students to use mobile devices to contribute textual evidence (e.g., written descriptions) and visual evidence (e.g., photographs and videos) to a shared repository (Quintana, 2012). Students can review their own textual and visual data and that of their peers, and use these data to support knowledge claims. These skills align with a third NGSS practice—*analyzing and interpreting data*. They are also consistent with an expectation from the Ontario curriculum, which is that students *communicate findings* using a variety of forms, including oral, written, and visual formats (Ontario Ministry of Education, 2007). However, such use of visual evidence may introduce new challenges, and more work is needed to understand how learners make produce and make sense of visual forms (Ainsworth et al., 2011).

Neighborhood Safari: Using visual evidence to support planning

A six-week unit engaged middle school students in schoolyard investigations of urban wildlife using motion-activated cameras called "camera traps." Students set out several camera traps in succession, collecting and using images from different locations to collaboratively understand patterns of animal behavior. Students strategically positioned their camera traps in the schoolyard four times, for a period of 2-3 days each. One goal was for students to become proficient at planning investigations (i.e., *where* to place the camera trap) based on environmental cues (e.g., potential food sources) and previous results (e.g., animal sightings).

Method

Students (n=45) from two Grade 5/6 classes from an elementary school in Ontario, Canada participated in the first case study. Student groups used a Web-based application for mobile devices called Common Knowledge (Fong et al., 2013) to share investigation plans with peers. Software scaffolds prompted students to describe where they would place their camera trap, provide a rationale for camera trap placement, and attach justificatory photographs (e.g., of an annotated schoolyard map; see Figure 1). These notes were contributed to a shared knowledge base, and students were able to view the contributions of other groups in real time.

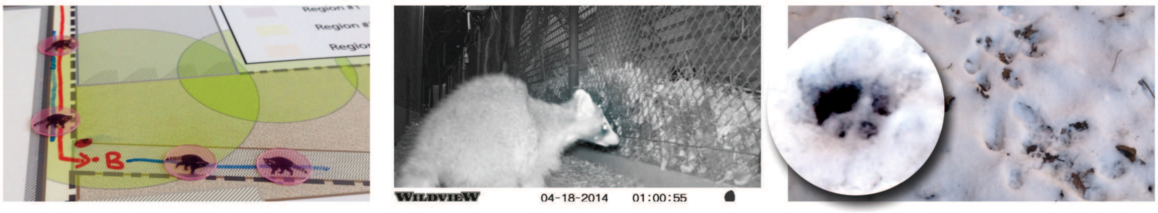

Figure 1. Left: Detail of planning map, Middle: Camera trap photo of raccoon, Right: iPad photo of footprints

Analysis and findings

We analyzed the planning notes that contained a discernable plan (n=46). First we identified the plan from each note, and then we compared textual support (i.e., the written rationale students gave for their plan) and visual support (i.e., the justificatory photographs) against each plan.

Table 1: Coding scheme for Neighborhood Safari planning notes

Level	Textual support by students for plan	Visual support by students for plan
0	No rationale given for the plan.	No justificatory photographs attached to the plan.
1	Text provides an **unreasonable** expectation for the plan (e.g., *We expect to see if the raccoon is female).*	Photograph was **irrelevant** to the plan (e.g., photograph of two students in their classroom)
2	Some of the text provides a **partially reasonable** expectation for the plan, but was too broad—*e.g., we want to see squirrels*—or contradictory).	Photograph(s) provide(s) **partial description** of plan (i.e., information needed to carry out the plan is missing).
3	Text provides a reasonable expectation for the plan and reasoning is **implicit** (e.g., *We expect to see raccoons by the garbage cans*).	Photograph(s) contain **descriptive elements** relating to the plan (e.g., map shows proposed location of camera trap).
4	Text provides evidence to support a reasonable expectation and reasoning is **explicit** (e.g., *We expect to see raccoons by the garbage cans because we have seen them there before).*	Photograph(s) provide(s) **justification** for plan (e.g., photo of planning map *and* camera trap photo of raccoons near garbage cans).

There were 65 photographs attached to these notes, with an average of 1.4 photographs per plan, ranging between 0-5 photographs per plan. Thirty-nine of the photographs were of maps, 15 were from camera traps, and 11 were taken using the iPad camera. Following the process outlined by Hruschka et al. (2004) for developing a reliable coding scheme, we created codes to assess the level of support provided by (1) textual evidence and (2) visual evidence for the plan. For both textual and visual support, we identified characteristics for five levels, from 0 (none) to 4 (highest; see Table 1).

The two raters independently coded 20% of the data, with IRR scores reaching perfect agreement for textual support and substantial agreement for visual support (Kappa=0.61, p=0.005). After independently coding all of the data, the raters reached agreement for all data through discussion. Analysis indicated that the level of textual support for plans was higher (M=3.5, SD=0.6) than visual support (M=2.67, SD=1.3).

EvoRoom/Zydeco: Using visual evidence to support argumentation

We engaged high school biology students in a 75-minute activity (part of a 10-week unit) concerning the long-term effects of climatic events (e.g., earthquake, tsunami, high sunlight, low rainfall) on a Borneo rainforest environment (Lui et al., 2014). An immersive simulation displayed four different scenarios (one per classroom wall), each of which visually depicted the effects of one climatic event (e.g., dry plants and soil indicated effects of low-rainfall). Using their knowledge of how various climatic events would impact biodiversity, student groups were tasked with identifying which of the four stations depicted their assigned climatic scenario.

Method

Students (n=51) in two Grade 11 biology classes from a high school in Toronto, Canada participated. Students used the Zydeco application (described previously) to: (1) make observations of the environment, (2) add a claim (e.g., "Station A is the rainforest affected by low rainfall") and, (3) justify their claim by explaining how the effects of a particular climatic event were evident. Using the iPad camera, students captured photographs of the simulation (either the entire screen or a detail shot – see Fig. 2) to provide evidence for their claims.

Figure 2. Left: EvoRoom, Middle: Student collecting evidence with Zydeco using iPad, Right: iPad photo detail

Analysis and findings

We analyzed the claim notes (n=33) written by student groups, coding separately the written explanations and the corpus of photographs that student-groups supplied as support for each claim. Captions that accompanied photographs were coded as part of the visual support. Ninety-six photographs were attached to these claims, with an average of 2.9 photographs per claim, ranging between 0 and 9 photographs per claim. The first two authors followed the process outlined previously to develop a coding scheme to assess levels of support provided by textual evidence and visual evidence for claims (see Table 2). For both textual and visual support, we identified characteristics for five levels, from 0 (none) to 4 (highest; see Table 2).

Table 2: Coding scheme for EvoRoom/Zydeco claim notes

Code	Textual support by students for claim	Visual support by students for claim
0	Text rationale is not provided	Photographic evidence is not provided
1	Text is **irrelevant** to the claim	Photograph is **irrelevant** to the claim (e.g., photograph of two students in their classroom)
2	Text provides **partial support** for the claim (i.e., some statements are contradictory or irrelevant).	Photographs provide **partial support** for claim (i.e., contradictory or irrelevant photographs are included).
3	Text provides **descriptive evidence** that is congruent with the claim and reasoning is **implicit**.	Photographs provide **support** for claim (e.g., an overview photograph of a simulation panel).
4	Text provides an **explanation of the evidence** and reasoning is **explicit**.	Photographs provide **convincing evidence** to support the claim, revealing specific useful details (e.g., close-ups of a simulation).

The two raters independently coded 20% of the data, with perfect agreement for textual evidence and substantial agreement for visual evidence (Kappa=0.7, p=0.001). All of the data was independently recoded, and the raters reached agreement for all data through discussion. Analysis indicated that the textual support for the claims was coded higher (M=3.0, SD=1.4) than visual support for claims (M=2.63, SD=1.34).

Conclusions and implications

For the purposes of analysis, we made a distinction between written evidence and visual evidence, although the note-sharing tools we used displayed text and photographs side-by-side, making them "colleagues in explanation" (Tufte, 2006, p. 83). However, it was important for us to tease these two evidence streams apart in order to understand if the quality of students' written support (text) differed from visual support (photographs). Our results showed that in both case studies, students achieved higher mean scores for textual evidence than for visual evidence. This suggests that these students had greater fluency in constructing written explanations that using visual evidence to support their reasoning, possibly due to curricular emphases on written literacy.

We examined the characteristics of high-level visual evidence in order to extract lessons concerning ways that learners can be supported in communicating findings using visual representations within technology-mediated environments. In Neighborhood Safari, high-level visual evidence often contained annotations (e.g., arrows drawn on a map) to provide justification for a camera trap placement plan. In EvoRoom, high-level visual evidence often included comparisons or contrasting images to more strongly illustrate claims. Captions also served to make connections between visual and written evidence more explicit. Students used compositional techniques (e.g., cropping to reveal specific details) to provide their peers with interpretive visual cues (Gilbert, 2008). These findings point to strategies that researchers and designers could use that would provide students with tools to facilitate tighter integration of textual and visual evidence, and expand work on how verbal and visual evidence are used to justify and dispute claims (e.g., Oestermeier & Hesse, 2000). For example, future designs may benefit from the ability to annotate photographs, such as the use of digital drawing tools (e.g., circles, arrows, text boxes) as overlays, drawing the viewer's attention to important elements within the visual representation. This could be particularly beneficial in cases where images are drawn from a shared knowledge base, for which students may be using a photograph for different reasons.

References

Ainsworth, S., Prain, V., & Tytler, R. (2011). Drawing to learn in science. *Science*, *333*(6046), 1096-7.

Coopmans, C., Vertesi, J., Lynch, M., & Woolgar, S. (Eds.). (2014). *Representation in scientific practice revisited*. Cambridge, MA: MIT Press.

Fong, C., Cober, R. M., Madeira, C. A., Messina, R., Murray, J., Peebles, B., & Slotta, J. D. (2013). Common Knowledge: Orchestrating Synchronously Blended F2F Discourse in the Elementary Classroom. *CSCL 2013 Conference Proceedings* (Vol. 2, pp. 26-29). Madison, WI,: ISLS...

Gilbert, J. K. (2008). Visualization: An emergent field of practice and enquiry in science education. In *Visualization: Theory and practice in science education* (pp. 3-24). Springer: Netherlands.

Hruschka, D. J., Schwartz, D., John, D. C. S., Picone-Decaro, E., Jenkins, R. A., & Carey, J. W. (2004). Reliability in coding open-ended data: Lessons learned from HIV behavioral research. *Field Methods*, *16*(3), 307-331.

Lui, M., Kuhn, A., Acosta, A., Quintana, C., & Slotta, J. D. (2014). Supporting learners in collecting and exploring data from immersive simulations in collective inquiry. *Proceedings of ACM SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*, (pp. 2103-2112). ACM Press.

NGSS Lead States (2013). *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press.

Oestermeier, U., & Hesse, F. W. (2000). Verbal and visual causal arguments.*Cognition*, *75*(1), 65-104.

Ontario Ministry of Education. (2007). *The Ontario Curriculum Grades 1-8: Science and Technology*. Retrieved from http://www.edu.gov.on.ca/eng/curriculum/elementary/scientec18currb.pdf

Peters, V. L., & Slotta, J. D. (2010). Scaffolding knowledge communities in the classroom: New opportunities in the Web 2.0 era. In M. J. Jacobson & P. Reimann (Eds.), *Designs for learning environments of the future: International perspectives from the learning sciences* (pp. 205-232). Secaucus, NJ: Springer.

Quintana, C. (2012). Pervasive science: Using mobile devices and the cloud to support science education. *interactions*, *19*(4), 76-80.

Scardamalia, M., & Bereiter, C. (1996). Student communities for the advancement of knowledge. *Communications of the ACM*, *39*(4), 36-37.

Tufte, E. R. (2006). *Beautiful evidence* (Vol. 1). Cheshire, CT: Graphics Press.

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