Integrating Eye-Tracking Activities Into a Learning Environment to Promote Collaborative Meta-Semiotic Reflection and Discourse

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Abstract: At the beginning of a one week science summer camp designed to promote student visual, scientific and data literacy, participants were recorded viewing infographics by an eye tracking-machine. Data were shared with participants the following day as fodder for discussion about data literacy, visual representations, and information processing. The eye-tracking activities helped make visible and public students' private visual strategies. Utilizing these data and other multi-modal representations students participated in a collaborative, metacognitive, reflective process regarding their own visual strategies, the mental processes of others, and comparisons within. This activity was one of an ensemble of technological activities and artifacts that afforded students a way to collaboratively engage with otherwise private, and often tacit thoughts. Results of this work in progress suggest that this sort of computer-supported intervention could be used productively to enhance student multi-semiotic discourse and collaborative reflective inquiry.

Introduction and major issues addressed

While there has been a growing interest in utilizing eye-tracking technology for educational research, much of this inquiry considers students subjects of research rather than active participants in learning environments. In a literature survey of 81 recent education research studies utilizing eye tracking technology, Lai et al (2013) found that overwhelmingly this work focused on attention, perception, or language while only 10 such studies considered learning strategies and instructional design. We have been exploring the promise of eye-tracking technology to be integrated in the design of computer-based learning environments, supporting collaborative and reflective meta-cognitive work and student centered discussion regarding multi-modal representational strategies, data literacy, and scientific communication (Kirsch, 2005). In this paper, we focus on how an eye tracking computer intervention can be integrated into the reflective and discursive activity structures of a learning environment. The specific intervention reported on here consisted of youth summer camp participants doing a laboratory supported study on the first day of camp, then collaboratively reflecting on otherwise private aspects of their visual processing and interpretation. The student generated meaning making that happened through a multi-semiotic, collaborative discussion of this activity served as a starting point for a series of activities and instruction leading up to students researching, designing, and publishing their own science news infographics.

We are concerned with how the use of technology and various representational modalities, eye tracking or otherwise, can bolster student self-reflection, discourse, and learning. Using a situated and distributed approach to cognition, we identify instances where metacognitive reflection occurs in the public sphere through discursive practice (Kirsh, 2005). In this work in progress, we aim to identify how a varied sociotechnical ensemble of discourse and action with technology (Hall, 2011) affords for productive collaborative, multi-representational engagement with otherwise private and tacit processes and thoughts.

Background and theoretical approach

We aim to expand the use of eye tracking technology in educational research beyond making claims about perception, cognition, or attention and more towards how such technology may be used to support collaborative learning activity within designed learning environments. Our small sample size (two interventions, nine students each) and methods do not allow us to make claims about intra-mental processes. Rather, our focus is the collaborative *inter*-mental meaning making processes that occurs when peer groups engage in multi-semiotic reflective discourse.

The InfoX camp and eye-tracking intervention are part of our broader study [STEM Literacy through Infographics] that considers how to best design learning environments to prepare students for STEM (science, technology, engineering, and mathematics) literacy in an era where *'text'* captures many communicative practices above and beyond the written word. Following Halsanova *et al* (2005) we are interested in how multi-modal forms of information presentation attentive to spatial continuity and dual scripting may render complex

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conceptual scientific content accessible to broad and diverse audiences across boundaries of language community or prior training. Beyond an explicit focus on learning environment design, we see cognition as situated and distributed, extending "beyond the skin" and utilizing social and material resources (Kirsh 2005; Pea, 1993; Schoenfeld, 1987). We see mediating artifacts as means to publically create and access knowledge. We consider that metacognition is not only a private phenomenon, but rather is frequently mediated through public interaction. Technology and media advances in the last twenty years allow, and in fact challenge us to expand the idea of meta-pragmatics and think deeply about multi-semiotic levels of communication that harness multiple forms of communicative tools towards information literacy (Silverstein, 1993; Stein, 2008). Building on Palincsar & Brown's (1987) notion of reciprocal teaching, we seek to design learning environments with cognitive tools for meta-cognitive awareness of visual perception and interpretation. We proceed in the spirit of Vygotsky's (1978) 'general genetic law', facilitating learners to first participate in the social exchange of cultural tools and ideas on the *inter*-mental plane (public) and later take up these ideas on the individual or *intra*-mental plane (Polman, 2004). Our hope is that technologically supported, multi-semiotic artifacts may help make visible private *intra*-mental processes, make these private processes public, and then encourage dialogic meta-cognitive reflection that has lasting *inter* and *intra*-mental consequence. In this sense our theoretical focus is on the design of learning environments that utilize technologically supported artifacts to scaffold activities drawing on student experience and collaborative reflection to build knowledge from experience.

Research context

The eye tracking intervention and reflective debrief were developed as part of a week-long science summer camp, Infographic Expression (or InfoX) designed to engage middle and high school students in a meaningful process of researching a topic of scientific relevance, analyzing related quantitative data, and designing and publishing a science news infographic of their own. We worked with staff from our institution's Cognitive Development Lab to design an activity that exposed students to computer supported data collection, helped them gain deeper insight into how they process visual representations, and produced a series of artifacts and data to serve reflection and discussion. Infographics were selected and modified to include various representational forms (e.g., text, maps, images, charts, etc.) and content into four specific pre-defined areas of interest (AOI) throughout an infographic. Each infographic had a variety of representational forms, redundancy in where and how information was presented, and a variety of complexity concerning specific information. The eye tracking software captured millisecond-level records of saccadic movement, time spent in each AOI, and overall gaze pattern. The nine participants were divided into three groups of three; each group with a unique set of infographics. Students viewed three infographics with different instructions for each trial. In trial 1 students were asked to offer written responses to specific questions that could be answered by looking at the infographic. Trial 2 allowed students thirty seconds to study a new infographic and remember what they deemed most important and striking. The third trial was like the first (specific questions asked) though all three groups saw the same infographic. After each question, the real time gaze tracing was played back for students. Upon completion of the three tasks, students were escorted to a second room to complete a question worksheet and offer immediate reflections. The following day, each student group reviewed the data collected by the eye tracker and together discussed the experience with the entire class. They discussed their prior beliefs about their visual strategies, reactions to the data collected on their gaze, and the trends, patterns, and differences revealed by comparing the results of their peers. In this sense, students' own innate private processes were made visible to them and also made public to the rest of classroom.

Methods

We conducted a qualitative case study with a particular focus on the artifacts and data collected in the 2016 cycle of InfoX. During the camp itself, members of our research team rotated roles as facilitators, participants, and data collectors. A video camera and audio device recorded the entire summer camp to capture instruction, student work time, class discussions, and peer-to-peer interaction. Other data collected and analyzed include student pre-intervention worksheets, worksheets filled out during the intervention, the eye tracking data itself, student drafts of infographic, group work documents, exit interviews, and running observational notes. The InfoX team debriefed daily and later discussed key findings, trends, and other observations with the larger research group of our ongoing study. For the scope of this short paper, we focus our attention on Group 2; William, age 14 and in the first year of secondary school, Vera, age 15 and in the second year of secondary school, and Abby, age 15 homeschooled.

Findings

On day two of the camp, student groups had an opportunity to review and explain the infographics they saw to the other groups in the class. While explaining their initial reactions, where they believed they looked, and strategies for finding specific information during the question prompted infographic trial, the members of Group 2 each explained that they looked at different parts of the infographic and justified their response. Vera believed she focused mainly on bar charts and text. William indicated that he focused elsewhere, "but mainly that's because I am naturally drawn to maps, cuz I am actually really good at [that]. " Abby explained "I think I spent a lot on [AOI] 1 and 3… Not exactly sure why, I say I like colors, but then I would have gone to 1 and 4. " The instructors then presented the actual quantified data (by way of bar charts) showing exactly how many milliseconds blinded participants spent in each AOI answering the questions; the students did not know which set of charts corresponded to whom. They speculated about which 'subject' of the study they were, based on the recollection they had just offered. William rightly guessed which data was his, stating, "Well I know who I am. It's simple… Well I mean it's kinda important to note that both [participant ID] 1608 and 1602 the numbers were ultimately the same. 1605 had like, spent a crazy amount of time on AOI 2. Just wanted to point that out." Though William rightly claimed that he was subject 1605, this evidence was contrary to his earlier claims, revealing that that he *did not* primarily look at the map representation, but instead focused on a technical doughnut chart.

Group 2 then explained to their peers what the content and their responses were to the second infographic trial with no specific questions. Vera, Abby, and William explained in what order and where they believed they focused their attention in thirty seconds of viewing this infographic, referring back to their perceived habits or visual preferences. Instructors then showed the thirty second real time gaze track of one of the subjects, noting during the video that the data presented did not line up to the students' earlier claims. William quickly responded, "Well whoever did this one honestly has a hard time digesting a lot of information," and Abby claimed "I don't think it was me cuz I definitely looked at the pictures." Though Vera did not have a strong reaction, she did not argue that this might have been her info, as in fact it was. Groups A and B similarly shared out. In all three groups students recognized that their particular visual strategies varied from their peers, even when looking at the same infographic. Some students accurately identified what 'subject' they were based on the charts showing time spent in particular AOIs, though other students could not, and in some cases actually challenged that the computer did not accurately capture where their eyes 'really went'.

Lastly the class collectively reflected on and discussed their intuitions about their own ways of seeing, patterns about their visual processes revealed by the eye tracker, variations regarding visual literacy, considerations of different forms of data representation, and overall feedback for the design of the activity and what makes a 'good' infographic.

Through the course of the one-week InfoX program we observed that students gained an increased and changing awareness of their own visual processing and interpretation strategies. At the start of the week, students articulated their pre-existing expectations about how they believed they viewed complex visual information, noting that that this was not something they regularly thought about. The eye tracking activity and subsequent group reflection revealed where students actually did look in three trials. For some, these data supported their pre-existing ideas. For others, these data challenged student expectations and self-images. As the students designed their own infographics, they regularly mentioned 'AOI's' and referred back to gaze pattern and representational forms that had grabbed their own or others' attention. These conversations influenced their draft versions and final products. Regarding the eye tracking intervention and creation of her infographic Vera reflected, "It was interesting. The results weren't exactly what I expected. " Rather than assuming all people would view the infographic the same way, she said she created her infographic "how I would like to see it and also how people might want to see it." Vera's claims suggest that the eye tracking intervention served to prompt students' collaborative meta-cognitive reflection, perhaps revealing surprising insight. Further, the exercise and debrief appears to have influenced how students might focus in on the data rich components of visualization. Lastly, this activity informed students own communicative practice as they designed an infographic drawing on the principles observed in the activity.

Significance and implications of this work

The technology and multi-semiotic representational tools used in this program were intended to give students some exposure to an experience where they were both the 'subjects' of the study and also the researchers, interpreters and meaning makers. These interventions show promise at bolstering students' capacity to reflect on and discuss mental processes that were otherwise private and tacit. Once students gained an awareness of their own and also peer visual processed, InfoX instructors sequenced further activities to build upon this knowledge.

The InfoX program provided an opportunity to consider how technologically mediated lessons and activities can be utilized as early interventions to make students' visual processing visible to themselves and their peers. This work in progress illuminates how the processes of visualizing complex data, publically making sense of these data, and dialogically moving between the *inter* and *intra*-mental plane may empower students to draw from their own and their peers' prior and emergent knowledge to interpret and design infographics. This can inform the design of computer-supported collaborative learning environments that increase students' epistemic agency and ownership.

Future studies and learning environment design work might expand upon this line of inquiry in several directions. We will continue to explore how learning environments can be designed to expose otherwise private mental processes as a means towards guided, collaborative multi-semiotic discourse to drive understanding of STEM content. In these student-centered environments knowledge is built by the students, using technologically mediated semiotic 'texts,' and the instructors work mostly as collaborators or coaches. Further, we hope to bolster students' ability to communicate complex ideas with broad audiences. We support continued veins of research that consider how technologically informed learning environments might be developed to prioritize data accessibility, make mental processes visible, and bolsters students' ability to collaboratively engage in meta-cognitive work utilizing multiple representational forms.

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