Can Instructional Prompts Support Effective Learner Behaviors With Tangible and Digital 3D Models?

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Abstract: This study investigated the impact of instructional prompts on how learners interacted with two forms of 3D models during a science education task: tangible (3D prints) or digital (desktop-based) 3D models of fossils from a natural history museum collection. Learners observed and reasoned with 3D models to answer a scientific question. Two forms of instructional prompts were compared: functional prompts to manipulate the models in ways that explored how the fossil may have functioned, and general prompts to manipulate the models in ways that help answer the scientific question. Results suggest that functional prompts encouraged different participant interactions with tangible models, but not with digital models.

Keywords: Instructional prompts; 3D models; science learning; learner behaviors

Theoretical framework

As science instruction has come to increasingly emphasize authentic practices and approaches, there are concerns that science learning is "decontextualized from direct experiences with objects" (Dierking, 2002, p.4). With current initiatives at museums and academic institutions to digitize collections (Clough, 2013), students now have access to large open source libraries (e.g., morphosource.org) of collections for educational use. Digitized objects may counteract potential issues related to decontextualized learning, spur student engagement, increase personal reflection, and facilitate communication with others (Chatterjee, 2010; Dierking, 2002; Paris & Hapgood, 2002). Access to digitized collections coupled with 3D printing technology can increase the use of museum objects in the classroom, but questions remain about how these objects may support meaningful learning experiences.

In a recent study, Butcher and Orr (in preparation) found that students who spontaneously interacted with tangible and digital 3D models of fossils during an inquiry-based, science investigation used different interactive behaviors when working with each type of model. When students interacted with digital objects, they often engaged in rotational interactions related to basic observations (e.g., the bone is rough). While students interacting with tangible objects (3D prints) often rotated the model, they also engaged in functional interactions (e.g., clawing motion) more often. Further, learning processes (assessed by collaborative discourse) were found to be of greater depth (e.g., inferential statements) when students engaged in functional vs. rotational interactions. However, functional interactions did not occur frequently with either model type. Prompts have been shown to increase the overall interaction with models during learning (Stull, Hegarty, Dixon, & Stieff, 2012). However, these prompts are often focused on increasing general interaction by verbally asking the student to interact with the model or placing the model in the student's hands, but they do not prompt for specific interactions. This study explored whether instructional prompts influence the functional interactions exhibited by students while they learned with tangible or digital 3D models during a science activity.

Methodological approach and data sources

Data were collected with 50 undergraduate students from a large, public university in the western United States. Students were randomly assigned to a model type (tangible vs. digital) and a prompt type (general vs. functional). Tangible models (Figure 1A) were 3D printed (PLA) from laser scans of original fossils at the Natural History Museum of Utah. Digital models (Figure 1B) were hosted in a 3D modeling program (MeshLab) using the same laser scans. Prompts were designed to encourage either general interaction with the models (general prompt) or to increase interactions related to the object's function (functional prompt). The general prompt was: "Move and interact with the bone in any way that will help you answer these questions." The functional prompt was: "Move and interact with the bone in any way that will help you to see how it may have functioned in real life to help you answer these questions." Students thought aloud for five minutes per bone as they answered two questions: (1) What part of the dinosaur do you think this bone is from? (2) Was the dinosaur that this bone came from a carnivore or an herbivore? Videos of participants' interactions with the 3D models were coded for interactive behaviors. Rotational interactions were coded when the participant rotated the model on any axis; functional interactions were coded when participants moved the fossil to represent motion during life (e.g., chomping jaw).

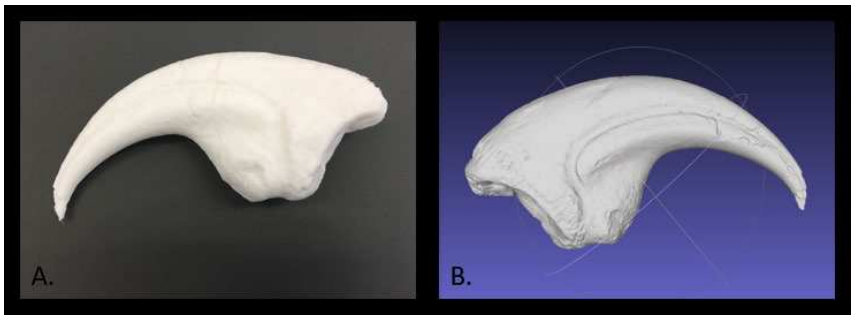

Figure 1. 3D models of the *Allosaurus fragilis* claw fossil. (A) Tangible 3D model printed in PLA; (B) Digital 3D model on a desktop computer.

Results

Main effects of model type were found for (A) total number of interactions ($F_{(1,46)} = 45.59$, $p < .01$), tangible $M = 118.5$, $SD = 56.13$, digital $M = 183.17$, $SD = 31.10$; (B) rotational interactions ($F_{(1,46)} = 119.06$, $p < .01$), tangible $M = 74.38$, $SD = 43.48$, digital $M = 179.96$, $SD = 30.18$; and (C) functional interactions ($F_{(1,46)} = 46.68$, $p < .01$), tangible $M = 16.23$, $SD = 13.74$, digital $M = 1.71$, $SD = 3.03$.

There was no main effect of prompt type on total number of interactions ($F < 1$). There were main effects of prompt type on model interactions: (A) rotational interactions ($F_{(1,46)} = 13.80$, $p = .001$), functional prompt $M = 106.04$, $SD = 64.15$, general prompt $M = 145.67$, $SD = 60.74$; and (B) functional interactions ($F_{(1,46)} = 22.68$, $p < .01$), functional prompt $M = 14.31$, $SD = 15.25$, general prompt $M = 3.79$, $SD = 3.99$;.

There was a significant interaction between model type and prompt type for total number of interactions ($F_{(1,46)} = 5.15$, $p = .05$), tangible model + functional prompt $M = 123.21$, $SD = 33.45$, tangible model + general prompt $M = 113.02$, $SD = 19.24$, digital model + functional prompt $M = 166.42$, $SD = 19.24$, and digital model + general prompt $M = 199.92$, $SD = 35.79$). There was no interaction found between model type and prompt type for rotational interactions ($F < 1$). There was a significant interaction between model type and prompt type for functional interactions ($F_{(1,46)} = 27.22$, $p < .01$), tangible model + functional prompt $M = 25.51$, $SD = 12.20$, tangible model + general prompt $M = 5.42$, $SD = 4.01$, digital model + functional prompt $M = 1.250$, $SD = 2.70$, and digital model + general prompt $M = 199.92$, $SD = 35.79$.

Discussion

The current results demonstrate clear differences in how students choose to interact with tangible and digital 3D models of the same objects. Findings show that targeted (functional) prompts can increase the frequency of meaningful interactions with tangible 3D models but not digital 3D models. Ongoing work is assessing the degree to which varied interactive behaviors are reliably associated with depth of processing in the learning task. More work will be needed to assess transfer of these findings to different types of object models. However, results demonstrate the importance of considering both model type and instructional supports when determining how and when students may learn deeply with 3D models during object-based learning.

References

Butcher, K. R., & Orr, M. (In preparation). The Impact of physicality on model-based learning.

Chatterjee, H. (2010). Object-based learning in higher education: The pedagogical power of museums. *University Museums and Collections Journal, 3*, 179 - 181.

Clough, G. W. (2013). *Best of both worlds : museums, libraries, and archives in a digital age*: Washington, D.C. : Smithsonian Institution.

Dierking, L. (2002). The role of context in children's learning from objects and experiences. In *Perspectives on object-centered learning in museums.* (pp. 3-18). Mahwah, NJ: Erlbaum.

Paris, S. G., & Hapgood, S. E. (2002). Children learning with objects in informal learning environments. In S. G. Paris (Ed.), *Perspectives on object-centered learning in museums* (pp. 37-54). Mahwah, NJ: Erlbaum.

Stull, A. T., Hegarty, M., Dixon, B., & Stieff, M. (2012). Representational Translation With Concrete Models in Organic Chemistry. *Cognition and Instruction, 30*(4), 404-434. doi:10.1080/07370008.2012.719956