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 used 3D models to engage in observation and reasoning to determine the type of bone that was modeled and whether the dinosaur that the bone came from was a carnivore or herbivore. Two forms of instructional prompts were compared: functional prompts that encouraged learners to manipulate the models in ways that allowed them to determine how the fossil may have functioned in real life, and general prompts that simply encouraged learners to use models to help them complete the task. Results suggest that functional prompts encourage different participant interactions with tangible 3D models, but not with digital 3D models.

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

Theoretical framework

As science instruction has come to increasingly emphasize authentic practices and approaches, an important consideration is the extent to which scientific investigations in the classroom may be "decontextualized from direct experiences with objects" (Dierking, 2002, p.4). With current initiatives at museums and academic institutions to digitize their collections (Clough, 2013), students now have access to large open source libraries (e.g., morphosource.org) of collections for use in educational settings. These items 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). While access to these digital files coupled with 3D printing technology may increase the use of museum objects in the classroom, significant questions remain about how and to what extent these objects support meaningful learning experiences for students.

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 the tangible vs. digital 3D models. When students interacted with digital objects, they often engaged in rotational interactions – which were related to basic observations (e.g., the bone is rough). While students interacting with the tangible objects (3D prints) often rotated the model, they chose to engage in functional interactions (e.g., clawing motion) more often. Further, learning processes (assessed by collaborative discourse) were found to of greater depth (e.g., inferential statements) when students engaged in functional interactions compared to rotational interactions. However, functional interactions did not occur at a high frequency with either model type. A key question emerging from this study is whether functional interactions can be prompted to increase the occurrence of a desired interactive behavior with tangible and digital 3D models.

Prompts have been shown to increase the overall interaction with models during learning (Stull, Hegarty, Dixon, & Stieff, 2012). However, often prompts are focused on increasing general interaction by verbally encouraging the student to interact with the model, but they do not prompt for specific interactions. This study seeks to answer the question; can instructional prompts influence the functional interactions exhibited by students while they learn with tangible or digital 3D models (in this case, a 3D print or 3D digital model of dinosaur fossils) during a science learning activity.

Methodological approach and data sources

We present data from 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 to a prompt type (general vs. functional). The tangible models (Figure 1A) were 3D printed (PLA) from laser scans of original items at the Natural History Museum of Utah. The digital models (Figure 1B) were hosted in a 3D modeling program (MeshLab) using the same laser scans. The 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 were asked to think aloud for five minutes per bone to answer 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 three interactive behaviors: rotational, functional, or elaborative. A behavior was coded as rotational if the participant rotated the model on any axis. A behavior was coded as functional if the participant used the model in a way that represented functional motion (e.g., chomping jaw). A behavior was coded as elaborative if the participant used action or gesture to indicate/simulate structures that were not present (e.g., fleshy outer structure).

Results

Model Type

There was a main effect of model type on rotational interactions ($F_{(1,46)} = 119.06$, $p < .01$). Rotational interactions averaged 74.38 ($SD = 43.48$) for tangible models and 179.96 ($SD = 30.18$) for digital models.

There was a main effect of model type on functional interactions ($F_{(1,46)} = 46.68$, $p < .01$); functional interactions averaged 16.23 ($SD = 13.74$) for tangible models and 1.708 ($SD = 3.028$) for digital models.

There was a main effect found for elaborative interactions ($F_{(1,46)} = 65.02$, $p < .01$). Elaborative interactions averaged 27.88 ($SD = 21.62$) for tangible models and 1.50 ($SD = 3.65$) for digital models.

Prompt Type

There was a main effect of prompt type on rotational interactions ($F_{(1,46)} = 13.80$, $p = .001$); rotational interactions averaged 106.04 ($SD = 64.15$) for those who received a functional prompt and 145.667 ($SD = 60.740$) for those who received a general prompt.

There also was a main effect of prompt type on functional interactions ($F_{(1,46)} = 22.68$, $p < .01$); functional interactions averaged 14.31 ($SD = 15.25$) for those who received a functional prompt and 3.79 ($SD = 3.99$) for those who received a general prompt.

A main effect of prompt type also was found for elaborative interactions ($F_{(1,46)} = 20.62$, $p < .01$); elaborative interactions averaged 22.81 ($SD = 25.09$) for those who received a functional prompt and 7.04 ($SD = 8.89$) for those who received a general prompt.

Interactions

There was no interaction found between model type and prompt type for rotational interactions ($F < 1$). Rotational interactions averaged 55.35 ($SD = 32.68$) for those who used a tangible model and received a functional prompt, 96.58 ($SD = 45.12$) for those who used a tangible model and received a general prompt, 165.17 ($SD = 31.71$) for those who used a digital model and received a functional prompt, and 194.75 ($SD = 20.52$) for those who used a digital model and received a general prompt.

There was a significant interaction found between model type and prompt type for functional interactions ($F_{(1,46)} = 27.22$, $p < .01$); functional interactions averaged 25.51 ($SD = 12.201$) for those who used a tangible model and received an functional prompt, 5.416 ($SD = 4.01$) for those who used a tangible model and received a general prompt, 1.250 ($SD = 2.701$) for those who used a digital model and received a functional prompt, 2.167 ($SD = 3.379$) for those who used a digital model and received a general prompt.

There also was a significant interaction found between model type and prompt type on elaborative interactions ($F_{(1,46)} = 30.27$, $p < .01$). Elaborative interactions averaged 42.36 ($SD = 17.87$) for those who used a tangible model and received a functional prompt, 11.02 ($SD = 10.36$) for those who used a tangible model and received a general prompt, and 3.011 ($SD = 4.786$) for those who used a digital model and received a general prompt; no elaborative interactions were found for those who used a digital model and received a functional prompt.

Discussion

The current results demonstrate clear differences in how students choose to interact with tangible and digital 3D models of the same objects, and that targeted prompts do 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.

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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, US: Lawrence Erlbaum Associates Publishers.

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: Lawrence 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

Figures

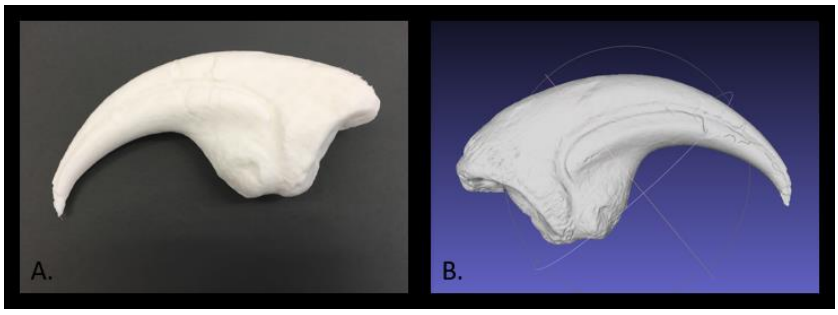

Figure 1. 3D models of the *Allosaurus fragilis* claw fossil. (A) Tangible 3D model printed in PLA; (B) Digital 3D model on a desktop computer.