Draw to Learn Science

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BACKGROUND

It is well established pictures improve memory recall better than words alone[6 7] and our pedagogy capitalize on this effect through the use of illustrations, diagrams, and photographs in educational materials. Illustrations benefit meaningful learning as they summarize verbal information into a concrete representation, often depict spatial relations that are not easily communicated verbally, encourage engagement, and prompt the learner to identify gaps in their understanding. [1 2]

A developing body of literature explores whether asking students to create their own drawings to represent what they are learning about benefits learning more so than studying provided illustrations[3]. Most studies on drawing-to-learn use lessons about scientific phenomena that have an observable physical presence (e.g., the mechanics of an air pump, the circulatory system), and find that novices learn best when the drawing process is guided by an instructor.[3] But, is the pattern of these effects dependent on the learning material itself?

The present study extends this research to the design of methods that help students learn scientific concepts that do not have a definitive visual representation. For theoretical concepts, it may be less important that students draw exactly what an instructor would produce as these representations are arbitrary. Therefore, student self-generated drawings may improve learning because they allow students to produce personally meaningful representations while more effectively capturing students' thinking.

RESEARCH QUESTION

When the learning material is theoretical in nature, do student generated drawings improve retention and/or transfer of the material in the lesson more than instructor provided illustrations?

HYPOTHESES

We hypothesize that:

1. the learning benefits of illustrations during the reading period will increase as participants generate more of their own drawings (from *a to d*): ***a.*** Study a provide illustration, ***b.*** Copy a provided illustration ***c.*** Complete a provided ***d.*** Create a novel drawing.

DESIGN

- n = 193 undergraduates, 14 excluded, M_{age} = 20.3
- 100 low prior knowledge and 79 high prior knowledge learners.
- All students read a 1607-word passage about the formation and properties of black holes.

Measures:

1. Vividness of Visual Imagery Questionnaire (VVIQ)[4] – 16 items
2. A validated cognitive load questionnaire[5]

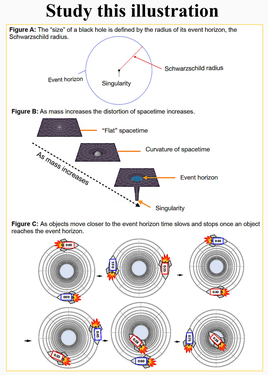
Multiple choice test: two versions of a 13-question multiple choice test were created – students were randomly assigned to complete one as a pre-test and the other as a post-test.

Retention & Transfer tests:

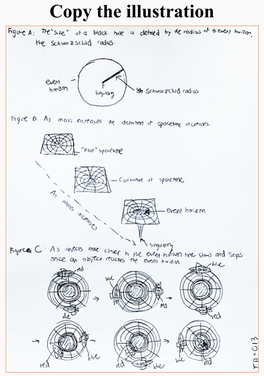
- **"**How do black holes form?"
- "A supernova explosion produces a neutron star. Why didn't it make a black hole?"

MATERIALS & METHODS

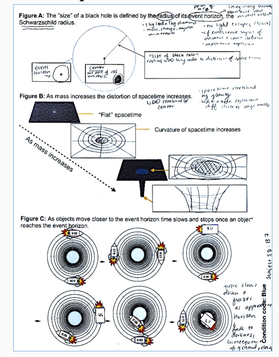
Study this illustration



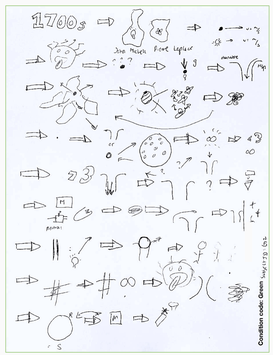
Copy the illustration



Complete this illustration



Draw to make sense of the text



Generative learning increases as students produce more of their own drawing

Study
n = 49

Copy
n = 48

Complete
n = 43

Draw
n = 39

Self-reported prior knowledge
Likert scale

Pre-test
13 multiple choice questions*

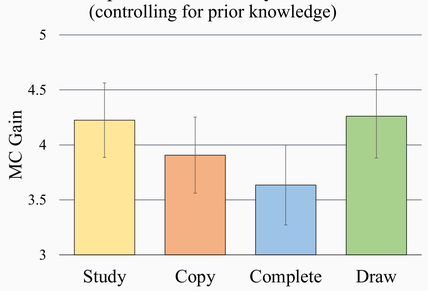
Self-reported cognitive load[5]
14 items

Post-test
13 multiple choice*, 2 recall, and 3 transfer questions

Visual Imagery Questionnaire[4]
16 items

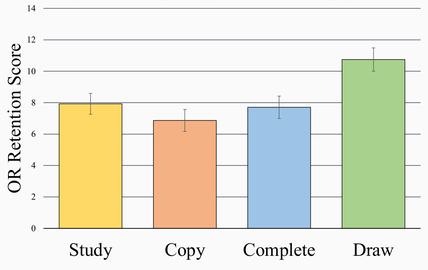
RESULTS

Multiple Choice Gain by Condition
(controlling for prior knowledge)



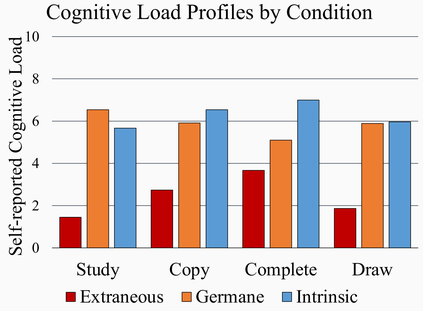
F(7,171) = 0.522, p = 0.817

Retention by Condition
(controlling for prior knowledge)

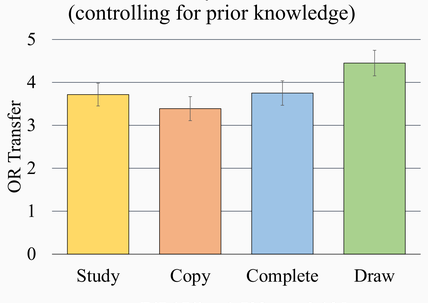


F(7,171) = 3.664, p = 0.001

Cognitive Load Profiles by Condition



Transfer by Condition
(controlling for prior knowledge)



F(7,171) = 1.732, p = 0.105

DISCUSSION

For the multiple-choice gain, we found no significant main effect of drawing condition, prior-knowledge, or their interaction F(7,171) = 0.522, p=0.817.

For the open response questions, we found a significant main effect of drawing condition on retention, (F(3,175) = 5.345, p = 0.0015) but not on transfer. We also found a significant main effect of prior knowledge F(1,178)=5.401, p=0.0213) on retention but not on transfer. No other main effects or interactions reached p>0.05.

Follow up pairwise comparisons using Tukey HSD suggest that the draw condition performed significantly higher on the open response retention questions compared to all other conditions, but study, copy, and complete were no different from one another. Bellow are all significant pairwise comparisons.

Level	Difference	P-value
Draw vs. Copy	4.23	0.0002
Draw vs. Complete	3.16	0.0134
Draw vs. Study	2.82	0.0274

The results suggest that students may benefit from producing their own drawings when learning theoretical concepts.

FUTURE DIRECTIONS

Explore differences in the organization of space of learner-generated drawings (e.g., center-surround, vertical, horizontal, grouping, continuum, proximity). May the use of space of a student's drawing be related to their learning from the passage?

Explore whether this effect holds true with other conceptual concepts (e.g., learning evolution, experimental design).

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