Learning About Dynamic Systems by Drawing For Yourself and For Others

Shaaron Ainsworth, Josie Galpin and Susannah Musgrove
School of Psychology, and Learning Sciences Research Institute
University of Nottingham

Abstract: The construction of graphical representations such as diagrams has been found to be a successful learning strategy in a variety of domains including dynamic mental model development. This investigation explored whether it was beneficial to construct a diagram for oneself or for another person when learning about the cardio-vascular system. It also explored if individual differences in spatial ability mediated this effect. Forty 18-22 yr olds studied text passages about the human circulatory system and then constructed diagrams containing information from these passages; twenty constructed diagrams under instructions to draw them to aid their own learning and twenty constructed the diagrams with the instructions to draw them for another (low knowledge) person. Results showed that although all participants learnt from the task, there was no differences if one draw for others or oneself. However, drawing for others led to diagrams that were judged as significantly clearer, as containing more of the presented information, and which used more words, but that took twice as long to create The quality of drawings was had a limited impact on what students' learnt – those students who translated more written text gained greater factual knowledge. There was no relationship with the measures of spatial abilities assessed.

Introduction

Recently, attention has been focused on learning by constructing visualisations rather than interpreting them (see Van Meter & Garner, 2005 for a review). For example, Grossen & Carnine, (1990) found that self-constructed drawing lead to deeper understanding and speculated that this was because the active process of construction promotes a deeper level of processing of the material.

Drawing diagrams when presented with written text has been found to be a successful way to learn about dynamic systems. A number of studies have presented learners with texts and then asked them to draw diagrams about what they read. For example, Gobert & Clement (1999), found that students who generated diagrams rather than text summaries whilst reading about of plate tectonics performed significantly better on post-tests as they developed more complex and complete mental models. Ainsworth & Iacovides (2005) found that learners could develop an equally rich understanding of the cardio-vascular system if they drew “self explanations” rather than wrote them (see Figure 1) and this overcame a learning from text disadvantage which had been found in previous studies.

Text which the student read	Self Explanation Diagram
“Human life depends on the distribution of oxygen, hormones, and nutrients to the cells in all parts of the body”	

Figure 1. A self explanation diagram

However, compared to research on building dynamic mental models from presented visualizations, work on constructing visualizations in still its in infancy. This study was therefore designed to assess if learning by constructing visualisations was affected by whom who were drawing them for – yourself or someone else.

There is some research in nondiagrammatic modalities compared explaining to oneself or for others. For example, Coleman et al. (1997) found that reading about evolution and then explaining it with the intent to teach another was more beneficial to learning than explaining for one’s own learning.. Bargh & Schul (1980) found that, in a psychology domain, students who studied in order to teach another person outperformed students who studied for their own learning on a subsequent retention task. Furthermore, the expectation of teaching another may cause a student to spend longer studying the to-be-learned information (Biswas et al, 2001), which may increase the amount of learning.

Finally, we wished to explored if there were any individual differences in spatial abilities that can affect the way students construct diagrams from text. For example, Heiser & Tversky (2003) found that the diagrammatic instructions of those high in spatial ability contained less errors, showed more depictions of actions and motion and were more likely to represent multiple perspectives.

Current Study

Participants

40 participants were randomly assigned to a "drawing for self" or "drawing for others" condition. All were university undergraduates 18-22 years of age who had not studied biology past the age of 16

Design

The experiment adopted a two-factor mixed design. The first factor was time (pre-test vs. post-test) and was within-groups. The second factor was the instruction in type of diagrams (diagrams to aid own learning vs. diagrams to aid another's learning). .

Procedure

Participants took the four proposed tests of spatial abilities (Shepard and Metzler's (1971) Mental Rotation, a Learning Styles Questionnaire, Mark Vividness of Visual Imagery Questionnaire, and Raven's Progressive Matrices) and then completed three pre-tests which assessed factual knowledge (blood path diagrams, multi-choice questions and definitions). One week later they returned and studied a text about the structure and functioning of the cardio-vascular system. 13 passages of texts containing information about the human circulatory system appeared on the computer screen in turn. After studying each text passage, subjects created a diagram illustrating what they had learnt from the passage, without referring back to the text. Half of the participants were asked to draw the diagrams to aid their own learning, whilst the other half drew the diagrams to aid the learning of another person. The 'recipient' of the diagram was described to the subject as having not studied biology past the age of 16 (i.e. a similar level of knowledge to the subject). No time limit was enforced for either the studying of the passages or the drawing of the diagrams, although the time taken for each was recorded. Finally, they took a post-test that included the pre-tests plus implicit questions (requiring integration of information) and knowledge inference questions (requiring generation of new knowledge), which are tests of appropriate mental model construction.

Results

Learning Outcomes

Analysis found a significant effect for time for the blood path diagram ($F(1,38)=89.821$, $p<0.001$), definition questions ($F(1,38)=288.3$, $p<0.001$) and the multiple-choice questions ($F(1,38)=255.8$, $p<0.001$). Participants on both conditions improved equally over time.

Table 1. Factual Scores by Condition and Time

	Path diagram (/ 12)				Definitions (/ 24)				Multiple choice (/10)			
	Self		Other		Self		Other		Self		Other	
	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D
Pre-test	3.8	2.3	4.0	2.3	6.2	2.6	6.5	2.7	4.7	1.8	4.2	1.4
Post-test	7.8	2.6	7.4	2.7	15.5	2.1	14.8	3.6	8.9	1.5	8.9	1.5

Analysis of questions testing deeper understanding also revealed no effect of condition (Table 2) on either the implicit, ($F(1,38) = .93$); or the knowledge inference questions, ($F(1,38) = .04$).

Table 2. Scores for Implicit and Knowledge Inference Questions by Condition

	Implicit (/ 16)				Knowledge Inference (/ 17)			
	Self		Other		Self		Other	
	X	S.D	X	S.D	X	S.D	X	S.D
Post-test	8.7	2.4	7.8	3.1	6.2	2.5	6.3	2.2

Drawing Scores

Participants' drawings in the two conditions were coded and analyzed along four dimensions; content, type, clarity and number of words (Table 3) **Content** refers to the amount of information in each text passage that was included in the corresponding diagram . The text was broken down into the key elements that were felt to be important for learning (this was performed until agreement reached 100% between researchers0. Then each element that was included in the diagram was given a point **Type** measures the to extent to which the diagrams were abstract or concrete/realistic on a 5 point scale. 1): Text only, 2) No realism, a symbolic representation; 3) Uses physical layout but violates physical contracts 4) Physical layout with attempts to use relative size and 3d 5) Attempts isomorphism. **Clarity** was marked on a three point scale based on subjective impressive on comprehensibility. **Number of words** is simply a word count of labels and titles associated with the diagram. Inter-rater reliability has been calculated for type and clarity and found to reliable ($K = .87, p<0.001$ and $K = .72, p<0.001$)

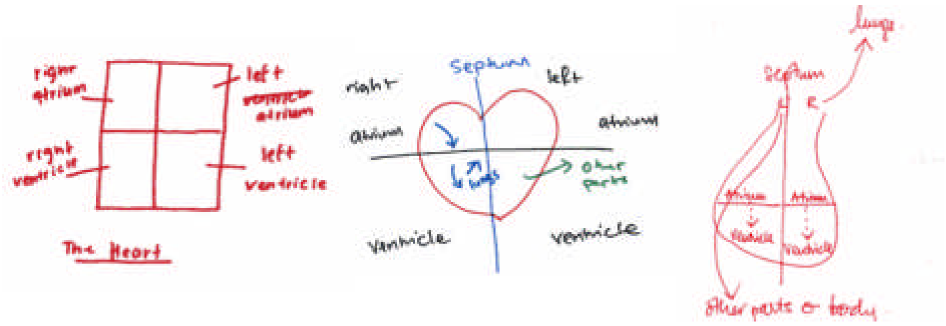

Figure 2. Abstract to Concrete Diagrams (scores 2-4)

Participants who were asked to draw diagrams for others translated more information from text to diagrams as they had higher content scores ($F(1,38)=3.9, p=0.05$), they also were judged to have clearer diagrams $F(1,38)=3.7$, $p=0.06$) and were found to have used more words ($F(1,38)=12.4$, $p<0.001$). There was no impact upon the concreteness of the diagram. Unsurprisingly given this pattern of results, participants drawing for others took longer to draw their diagrams ($F(1,36)=$ 13.3, $p<0.001$) and also to read the original text $F(1,36)=$, 4.04, $p=0.052$). (A MANCOVA calculated with these timings as covariates did not change the results for learning outcomes).

<u>Table 3. Drawing Scores by Condition.</u>

	Self		Other	
	X	S.D	X	S.D
Content (% translated from the text)	77.7%	8.5%	83.3%	5.9%
Type (abstract to concrete 1-5)	2.8	0.6	2.94	0.5
Clarity (clear to unclear 1-3)	2.3	0.4	2.5	0.4
Number of Words per Diagram	16.7	7.9	25.3	7.5
Time spent reading in secs(per section of text)	71.6	20.6	88.9	31.5
Time spent drawing in secs (per section of text)	122.9	58.8	214.9	92.9

The drawing scores has some relationship to what students learnt – content scores correlated with factual post-test scores ($r=.37$, $p<0.02$). Type scores correlated with deeper knowledge post-test scores (.32, $p<0.05$), but also with pre-test scores (.38, $p<0.015$). Participants did not learn more if they spent longer drawing or reading.

<u>Effect of Spatial Abilities</u>

There was no significant correlation between any of the purported measures of spatial ability, There was also no relation with these scores and pre or post-test performance and the drawing scores.

Discussion

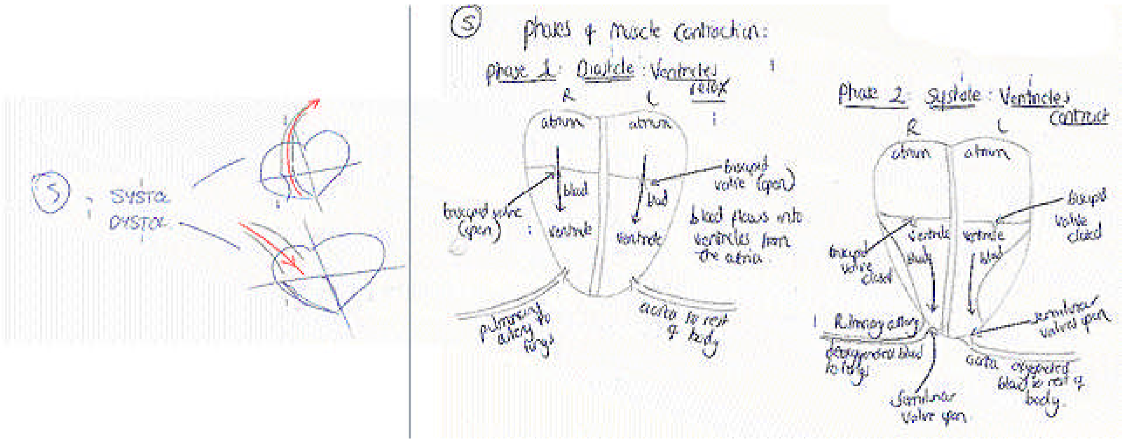

Figure 1. A Self v Other Diagram

All participants learnt a considerable amount about the cardio-vascular system by, irrespective of whether diagrams were drawn for themselves or for other. This finding may provide support for the already well-substantiated view that the construction of graphical representations facilitates learning (e.g. Gobert & Clement, 1999). Given the lack of relationship with the individual differences scores it also suggests that drawing diagrams is effective even if learners are considered to have less spatial abilities. However, it is possible that the majority of learning that took place was due to the reading of the text passages rather than the construction of the diagrams.

There was a limited relationship between what learners drew and what they learnt. Diagrams which included more content (i.e. students who translated more information from the text) were associated with higher scores at post-test on factual measures, but not on tests of mental model construction. Those students who drew concrete diagrams knew more about the domain to begin with. This is partly reminiscent of Butcher and Chi (2006) who found that the early correct mental model as assessed by drawing strongly predicted overall learning outcomes. Finally, there was no impact of spatial ability on learning by drawing – drawing is an effective strategy for learners with different characteristics and should not, for example, be restricted to ‘high spatials’.

Drawing for self or others impacted upon what students drew – diagrams were judged as clearer, contained more information and used more words (see Figure 3 for an example)- which accords with Cox (1999)'s proposal that personal representations are likely to be sparser and less fully labelled than public ones. That this did not impact on outcomes reminds us that although diagrams created for oneself may seem unclear, they can be relevant to the individual who constructed it, and can still aid learning. However, it is interesting that participants felt that additional text was needed to make diagrams comprehensible to others. There was no difference in the abstraction of the representations. This accords with the findings of Fay, Garrod and Lee, (2003) who found that it was only interaction between participants which led to drawings become more abstract – simply repeating drawings for others without interaction does not make them more abstract.

In summary, this study found that creating diagrams for others took twice as long as creating diagrams for oneself. This was because diagrams created for others were fuller – with more content and more explanatory labels. However, this did not lead these learners to come to understand more than learners who created diagrams for themselves. Therefore in this domain, it seems that learning can be facilitated by the act of translating text into diagrams irrespective of how "good" those diagrams are seen to be by others. However, much more work is needed to explore the processes and outcomes of drawing diagrams from text as a learning strategy.

References

Ainsworth, S.E., & Iacovides, I. (2005). Learning by constructing self-explanation diagrams. Paper presented at the 11th EARLI Conference.

Bargh, J. A., Schul, Y. (1980). On the cognitive benefits of teaching. Journal of *Educational. Psychology .* 72:593-604

Coleman, E.B., Brown, A.L., Rivkin, I.D. (1997). The effect of instructional explanations on learning from scientific texts. The Journal of the Learning Sciences, 6(4), 347-365.

Butcher, K.R., & Chi, M.T.H. (2006). How can diagrams scaffold text comprehension? Paper presented at the EARLI-SIG 2.

Cox, R. (1999). Representation construction, externalised cognition and individual differences. Learning and Instruction, 9, 343-363.

Fay, N., Garrod, S., Lee, J., & Oberlander, J. (2003). Understanding interactive graphical communication, *Proceedings of the 25th Annual Conference of the Cognitive Science Society*.

Gobert, J.D. & Clement, J.J. (1999). Effects of student-generated diagrams versus student-generated summaries on conceptual understanding of causal and dynamic knowledge in plate tectonics. Journal of Research in Science Teaching, 36, 39-53.

Van Meter, P., & Garner, J. (2005). The promise and practice of learner-generated drawing: Literature review and synthesis. Educational Psychology Review, 17, 285-325.