One diagram does not fit all: How undergraduate students interpret geologic rock patterns.

A Thesis Submitted to the University Honors Program
In Partial Fulfillment of the Requirements of the Baccalaureate Degree
With Upper Division Honors

Department Of
Geology and Environmental Geosciences

By
Alecia Eschenbrenner

DeKalb, Illinois

May 2016
University Honors Program

Capstone Approval Page

Capstone Title
One diagram does not fit all: How undergraduate students interpret geologic rock patterns.

Student Name __Alecia Eschenbrenner__

Faculty Supervisor ____Dr. Nicole LaDue____

Faculty Approval Signature __[signature]__

Department of ____Geology and Environmental Geosciences____

Date of Approval _____5/1/15_____
This study investigates the question: how do students evaluate patterns out of geologic context? To investigate this concept, we removed square blocks of the patterns from a geologic diagram, created a survey, and asked undergraduate students to decide the relative age of geologic patterns. Students were also asked to rank the patterns from oldest to youngest and give a reason why they answered the way they did. There was total 69 participants; 25 Art, 24 Geology, and 20 Non-science/Non-art majors after removing incomplete responses or unqualified participants. Art students needed to be enrolled in ART102 or have completed it, Geology students needed to have completed GEOL325, and Non-science/Non-art needed less than 9 credits in science. Results showed that
Geology students constructed a regressive sequence meaning they used their geology knowledge to arrange the patterns. Art students constructed a sequence of patterns from easiest to hardest to create in AutoCAD. Non-science/Non-art students were less conclusive but all responses related to everyday items. These findings support the prediction that prior knowledge affects the way students interpret science visuals. Teachers and professors should be prepared that their students have different backgrounds and may need to use diagrams that match their students’ background knowledge.
Title: One diagram does not fit all: How undergraduate students interpret geologic rock patterns.

Introduction

Visuals are an important part of science classrooms. They are used in textbooks for students as well as for scientists to communicate with each other. Students are tested on them in standardized tests. Visuals are particularly important in geology, which includes studying complex spatial phenomena that are often represented using complex diagrams (Kastens & Ishikawa, 2006). Diagrams are used with novices and experts even though “novices cannot distinguish between relevant and irrelevant information.” (Hegarty et al., 1991; Linn, 2003). Even “playing a critical role in communication of science concepts” (Patrick et al., 2005, p. 353), that are still not universalized. This leads to believe there is disconnect of information and images are not created with students in mind. Learners can only use so much of their “working memory” at one time and therefore images need to be made to limit the load on the learner (Cook, 2006). Diagrams need to be designed in mind that students can only keep track of a certain amount of information at a time and that amount of information is the working memory of the student.

One common type of representation in geology is the cross-sectional diagram of rock outcrops (figure 1). Variations of this diagram are used in geology to illustrate how flat sedimentary rocks stack on top of each other, with the oldest layer on the bottom and the youngest layer on the top. Geologists call this the Principle of Superposition. In some cases, igneous intrusions or faults cut across the layers (B in figure 1), indicating that they are younger than the layers they cut across. This relative dating of layers is called
the Principle of Cross-cutting Relations. Students who have learned these principles in class will know how to judge which layer is the youngest or oldest in the sequence of rocks. One question is whether students new to geology would interpret the visuals correctly.

Figure 1. Geology diagram of sedimentary layers (A, C, and D) cut by igneous rock (B) indicating that B is younger than C and D but A is younger than B.

Based on the pilot data from the summer of 2014, non-geology majors incorrectly evaluate patterns in geology diagrams. Students were shown the diagram (figure 1) and asked to determine which layer was the youngest. The interview responses suggested that Non-science students pay attention to the patterns in the rock layers rather than the geologic arrangement of the rock layers. Participant #9 in the pilot data responded that the youngest rock was C because “it looks brand new or fresh, it’s bricks or something” when asked to determine the youngest rock layer. In another case, participant #23 stated that “it's not yet been affected by the igneous rocks that's in contact with it” an answer based on the geology of the diagram. These two examples show that some students answer questions based on the patterns of the rock layers, while others draw upon some knowledge of geology. Geology has specific rules for which rock type is represented with each pattern. For example, in Figure 2, pattern A represents an igneous rock, pattern
B represents a sandstone sedimentary rock, pattern C represents limestone sedimentary rock, and pattern D represents shale sedimentary rock. In the pilot study, Non-science students interpreted these patterns in a non-geologic way, leading to incorrect answer.

Figure 2. Patterns used in geology to represent igneous rock (A), sandstone sedimentary rock (B), limestone sedimentary rock (C), and shale (D).

Knowledge of geology would influence how people view geology diagrams. In a study done with physics experts it was found that “salience will not influence the participants answers choices. Rather, it is the knowledge that learners already possess” (Madsen et al., 2013, p.2). Therefore it makes sense that Geology majors would do a better job understanding these patterns and diagrams than Non-science majors. The pilot data suggests that salient features of the patterns included in the diagram might distract or confuse students without background knowledge, which was found in Hegarty et al., 1991 and Linn, 2003. An interesting question is how often students new to geology are confused by the geologic patterns?

There is another group of interest is Art. Art majors have a distinct advantage over others when it comes to analyzing images. An example of this is the Fry-Ruskin model of artist methodology. In this methodology artists have “strategies that allow them
largely to forget what they know, and thereby eliminating perceptual biases” (Kozbelt et al., 2007, p.81). These strategies are taught in drawing classes and allow “relationships among elements” (Vogt et al., 2007) and “more scanning time on structural/abstract features” to be analyzed rather than a focus of individual objects.

There is research that states that “visual representations do not communicate understanding to all learners equally” and therefore causes an understanding gap between experts and novices (Patrick et al., 2005). This study looks at how prior knowledge of undergraduate students with different majors (Art, Geology, and Non-science/Non-art) influences their perception rock pattern age. This follows the idea that peoples’ knowledge is used to view the image and then that knowledge also affects how people perceive the context.

Research Questions

What would happen if you took the patterns out of geological context and had students look at the patterns themselves? The study was done to understand how the various majors (Art, Geology, and Non-science/Non-art) analyze the patterns out of geological context. Geology majors in contrast with artists have two different contexts to look at the image from, a pattern context and the prior knowledge of what the layers mean. When determining which is the oldest layer in a geologically correct image the arrangement shows which layers are older versus which are younger. When the patterns are separated from the layers, the first hypothesis is that the geologists will have to determine if they think pattern or geological meaning to the pattern is more important. Based on this knowledge, when the patterns are taken out of the image the geology majors will spend time sorting through their prior knowledge to determine age of the
pattern squares. For example, geology students may think the sedimentary rocks are younger because they are formed on the Earth’s surface.

Non-Science/Non-art and Art majors will be used as a control. The second hypothesis is that they will perform more based on relations of the patterns to outside objects than geologic significance. The third hypothesis is that Art students will use their knowledge on pattern creation to determine age of pattern. Non-Science/Non-art majors will not have the prior geology knowledge nor art training about salience; therefore they will perform based on comparing the patterns to objects they see around their everyday life.

This study will explore the differences between how various types of students understand visuals used in geoscience classes. This type of study is important because it will provide information relating to visuals and how students use them that may be helpful to teachers or professors in their classrooms. This research can also help textbook companies better design their visuals to reach more students. If we can determine who flourishes in what environments we may be able to lessen the gap between experts and novices and help guide in the creation of more easily understood visuals across every specialty.

Methods

The population surveyed for the study involved Art majors, Geology majors, and Non-science/Non-art majors. Each category had its own qualifications; Art majors needed to have completed or be currently enrolled in ART 102, 2-D Foundations, Geology majors needed to have completed GEOL 325, Solid Earth Composition, and Non-science/Non-art needed less than 9 credit hours in any science. These courses have
been selected due to their requirements for each major. Art 102 is when art students have established enough drawing ability to practice their perception. GEOL 325 was selected because students will have learned that the patterns have geologic meaning. Non-science/Non-art needed less than 9 credits to ensure they only had general education classes and not enough geology to give them the same edge as majors.

We used survey monkey to collect the data. To find participants, we advertised the survey on the Geology Department Facebook page, made announcements in Geology 335, sent an email to students in Geology 120. Two researchers from the lab visited introduction to Geology, and Art102 classes to ask for participation in the survey. There was a post on Facebook; as well as general flyers were hung in the Jack Arrends Art building, Holmes Student Center, and Davis hall.

The survey was designed to evaluate how students perceived four common geology rock patterns for igneous rock, sandstone, limestone, and shale when they are separated out of the geology images. For the survey we put the four rock types next to each other horizontally (Figure 2) instead of organized in vertical way that might imply a geologic relationship. Questions were asking participants to answer which is the youngest, the oldest and to explain verbally why they chose each in open-ended questions. The survey is appendix A.

In addition to asking questions about the patterns, we asked questions about the person’s background. The next page asked non-identifiable information about the participants to group them appropriately. These questions first ask for major. Each major choice reroutes to a different page with a list of classes in that major. After the students select the classes they are completed with the survey.
There were total 109 responses to the survey. After collecting all the survey data, the participants had to be filtered out for participants who either did not finish or were overqualified. Overqualified were double majors and over 10 credits in science. Then all participants who did not fill in the consent form were deleted as well. If someone did not answer the open-ended questions they were grouped as incomplete and their data was not analyzed.

After preparing the data, we had 24 Geology, 25 Art, and 20 Non-science/Non-art majors that were included in the study. The data analysis included totaling the number of students in each group, averaging the age of each group, and counting the number of participants from each academic level.

The data analysis of the questions included counting the oldest and youngest questions for number of responses of each letter for each major. Ranking questions were analyzed and totaled up for each position for each letter. Diagrams above show the ordering of patterns in each major. The highest number of participants that chose a certain pattern for a position (1, 2, 3, 4) was used in the diagram. Interestingly enough all three groups chose different orders for the patterns when asked to sort them.

Results

Most Art majors were freshman (10) and a few in each of the other years of academic standing (Table 1). In Geology, the majority was Grad Students (9) and for Non-Science/Non-art there are majority sophomores (12).
Table 1: The number of students in each age for each grouping:

<table>
<thead>
<tr>
<th>Year in School</th>
<th>Geology</th>
<th>Non-Science/Non-art</th>
<th>Art</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>0</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Sophomore</td>
<td>0</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Junior</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Senior</td>
<td>8</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Grad Student</td>
<td>9</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Post-back</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Each group selected a pattern as the youngest (table 2). For Geology, 12 of the students selected B as the youngest. For Non-science/Non-art, 10 participants selected the pattern A as the youngest; Art participants selected C as the youngest with a total of 11.

Geology students selected B as the youngest giving open-ended responses such as “because sandstone form in shallower environments than shales and limestones (carbonates)” (participant G22) or “it is the youngest part of a regressive sequence” (participant G2).

Non-science/Non-art selected A as the youngest. Participant N11 thought that the pattern was “new” and “never seen before”, making it the youngest. One other common response was demonstrated by N12, “it looks more modern because of the quirky design” or N20 who stated “its angular”.

Students in Art selected C as the youngest, giving reasons such as participant A2 who in the open ended responses said “the brick takes more effort and thinking of where to place lines”. Another common response by an Art participant was: “Because humans invented brick and humans are relatively young compared to the universe”; represented by participant A6.
Table 2: The selected pattern by each group for youngest:

<table>
<thead>
<tr>
<th>Youngest</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geology</td>
<td>2</td>
<td>12</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Non-science/Non-art</td>
<td>10</td>
<td>2</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Art</td>
<td>9</td>
<td>2</td>
<td>11</td>
<td>2</td>
</tr>
</tbody>
</table>

Each group selected a pattern as the oldest (table 3). For Geology, 16 of the students selected A as the oldest. For Art, 13 selected C as the youngest. Non-science/Non-art, the pattern C was also selected as the oldest with 11. Every group picked a different pattern for the oldest.

Geology majors selected A for the oldest. Participant G6 gave rational: “that is how I have seen old igneous basement rocks denoted on geologic maps and cross sections” and participant G12 referenced that: “Igneous must exist before other rock types form”.

Non-science/Non-art and Art selected B as the oldest. Their rational were quiet similar within Art but quite different from Non-science/Non-art. Art major participant A4 stated: “This pattern is the oldest to me because of the spastic nature of the movement of dots, making it very easy to replace or produce.” Participant A20 explained: “its the oldest of ideas, all things start with a point, a dot”. Art majors seemed to have a focus on the way the pattern was made, whereas the Non-science/Non-art majors seem to focus on the fact it resembles nature or that it is small. For example Non-science/Non-art participant N2 explained, “it reminds me of stars in the galaxy” and participant N19 explained that the pattern has the “smallest particles”.
Table 3: The selected pattern by each group for oldest:

<table>
<thead>
<tr>
<th>Oldest</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geology</td>
<td>16</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Non-science/</td>
<td>1</td>
<td>11</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Non-art</td>
<td>4</td>
<td>13</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

Each group was asked to organize the patterns from oldest to youngest. In Table 4 the spread of which letter were selected for what position for Non-science/Non-art.

Following, Table 5 for Geology and Table 6 for Art. In all tables position 1 is what was considered the youngest and 4 the oldest. Position 2 and 3 are the middle patterns. The highlighted squares show the trends in the data.

Table 4: Order of Patterns for Geology:

<table>
<thead>
<tr>
<th>Geology</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>12</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>7</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Overall Order: B C D A

Table 5: Order of Patterns for Non-science/Non-art:

<table>
<thead>
<tr>
<th>Non-science/Non-art</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>4</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>8</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

Overall Order: A D C B
Table 6: Order of Patterns for Art:

<table>
<thead>
<tr>
<th>Art</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>3</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>12</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

Overall Order: C A D B

Next, the patterns were reordered to put them back into geologic context based on how the participants responded to the ranking question. The following figures show a visual representation of the new orders for each group Geology [figure 1], (Non-science/Non-art [figure 2], Art [figure 3]). For each figure below the patterns are shown youngest on top to oldest on the bottom. This mocks up if you were to put the patterns selected into a geologic context.
Figure 3: Non-science/Non-art

Figure 4: Non-science/Non-art
Discussion

The purpose of the study was to determine if background knowledge that students possess will change the way they perceive patterns. The most obvious difference between the three types of majors was that Art and Non-science/Non-art were more similar to each other than they were to geology. The geology majors’ and art majors’ answers were more consistent within their group, whereas the Non-science/Non-art gave a bigger range of answer. A surprising finding was that t

As expected, the geology majors used their knowledge of bedrock geology and sequence stratigraphy to decide which type of rock was the oldest, youngest, and to put the rocks in order. The geologic setting of the region where this study took place also likely played a role. In the upper Midwest, igneous rock is associated with very ancient bedrock (greater than 1 billion years old). In most places, sedimentary rocks are found on top of the igneous rock. During the Paleozoic time period (540-250 million years ago), the Iapetus Ocean covered the Midwest, depositing limestone, sandstone and shale. The sequence of rocks layers: shale, limestone, then sandstone, represents what is called a regressive sequence. The shale is deposited in deep ocean water. Limestone is deposited offshore. Sandstone is deposited in a beach environment where an ocean meets the land. The sequence of layers chosen by the geology majors suggests that they used their understanding of the Paleozoic time period and the Midwest location to rank order the rock types.

The Non-science/Non-art results were a bit unorganized. The results from this group of participants did not seem to converge on whether C was youngest or 3rd in the sequence and if D was 2nd or 3rd in the sequence. This could be because there is an
abundance of possible majors with possible backgrounds. This also may be caused by their lack of background training in either geology, providing them with knowledge to use in interpreting the patterns, or art, providing with the perceptual training to interpret patterns. Non-science/Non-art reference nature and objects or patterns they are familiar with from other areas of their lives. The most surprising reason for choosing the youngest/oldest was…

Art majors’ responses were closer to Non-science/Non-art than Geology. Although Art majors were not as conclusive as Geology, they were more conclusive than Non-science/Non-art. This may be due to the fact that majority of participants in Art were freshman and may not have had enough art experience to be consistent in their answers. There was an overwhelming consensus that D in the third place and B as oldest. The reasons the students provided related to how easy these patterns are to construct in AutoCAD. For example, pattern B (figure 2) would be easier to construct than pattern A because every time you create an object in AutoCAD you need to program every hatch object (dot, line-segments or gaps) with its offset and angle. Therefore, pattern B being only dots allows for less parameters per hatch object than pattern A. The Art majors analyzed more on a basis of artistic creation then context.

Conclusion

Students participating in this study referenced their prior knowledge and training to interpret geologic patterns. Geology majors rely on what they know about each pattern from their geology classes. Non-science/Non-art students use information from the world around them to determine age differences in patterns, as they have no Geology or Art
experiences. Art majors use their knowledge of AutoCAD and determine concept of pattern age based on how you draw or construct the pattern in art.

The next steps are to take the student-selected patterns and put them back into geologic context (Figure 1) to compare how the groups identify the oldest/youngest rocks when they are arranged based on this study’s findings. The study should include eye tracking to identify where students look in a science image versus what they say they look at to analyze an image. The implications for this study are that patterns do not communicate to Non-science majors as professors might expect. We recommend that people teaching introductory geology courses be sure to teach the patterns before using these diagrams with students.

Recommendations for instructors of non-majors would be to keep in mind that not everyone comes from the same background. This leads students to have different perspectives when they look at the geology images. A suggestion would be to teach the patterns to the lower level classes so they understand the images better or to not use the patterns at all and teach general spacing and overall concepts about rock formation.
References


