Visualizing the Common Core State Standards

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Abstract:

Are the Common Core State Standards (CCSS), released in 2009, intuitively understandable? This paper attempts to address this question by separating individual standards from their subheadings to see if, and how, people reconstruct the standards under two conditions—with the subheadings or without the subheadings. The hypotheses are: subjects with subheadings to structure the standards will create more hierarchies; it will take them less time to complete the task; and they will find the task easier than those subjects who are only provided with the standards. Another hypothesis is that subjects will represent the information in both hierarchical and non-hierarchical format. In the study, subjects are asked to relate the standards together by creating a graphical representation. 44% of subjects in both conditions recreated the standards in a hierarchical representation that paralleled the CCSS, while 56% of subjects used alternate representations such as matrices and maps. While there did not appear to be significant differences between conditions based on whether or not subheading prompts were included, a secondary analyses showed that students enrolled in a course on visualization created more matrices than students not enrolled in the class.

Introduction:

Curriculum standards are developed as a means to guide instruction and provide consistent achievement benchmarks. Historically, individual states wrote their own standards, resulting in variable expectations between states. In 2009, working groups began collaborating on a set of common standards for math and language arts in an attempt to standardize instructional expectations across states. In June 2010, a set of Common Core State Standards (CCSS) were released in hopes that states would adapt these shared standards in order to provide consistent expectations for student achievement in math and English language arts (ELA) for grades K-12 (Education Northwest, n.d.). By completing the benchmarks outlined in these standards, the presumption is that students will be prepared to move forward to pursue either a career or a college education.

Now that the standards have been developed, the question is: "Are these standards written in such a way that they can be intuitively understood by teachers, parents and students?" A follow-up question might involve practical issues: "Now that common standards have been developed, can they be successfully implemented in the classroom?" Finally, we may ask about assessment: "How can we measure student mastery with these concepts and skills?" These are the questions and tasks that lay before us as we try to ascertain whether or not the Common Core Standards are reaching their desired goals.

Graphic visualizations such as hierarchies, concept maps, Venn diagrams, trees, matrices, and graphs help people organize information and make sense of it. In addition, good visualizations can help people see deeper structures in concepts and information. This paper is an exploratory study that attempts to address the first question posed above "Are the standards written in such a way that they can be intuitively understood by teachers, parents and students?" by having subjects create a graphic visualization of a subset of 1st grade math Common Core State Standards.

The CCSS 1st grade math standards are organized into four critical areas. Underneath each of these critical areas are topical subheadings. Individual standards are arranged under these subheadings. For example:

1. **Critical Area**: Geometry
    a. **Subheading**: Reason with shapes and their attributes

i. **Standard**: Distinguish between defining attributes (e.g., triangles are closed and three-sided) versus non-defining attributes (e.g., color, orientation, overall size); build and draw shapes to possess defining attributes (Common Core State Standards, n.d.).

But is this hierarchical arrangement with these particular Critical Areas and Subheadings consistent with how teachers, parents and students visualize the key concepts children must master before progressing to the second grade? Or are there alternative representations that would more effectively lend themselves to instruction? In order to investigate these questions, participants in this study are asked to create visualizations of a subset of standards under two different conditions—one with the subheading provided, and one without.

Hypotheses are:

1. Subjects with subheadings will create visualizations more consistent with the CCSS—hierarchies organized by these subheadings.
2. Subjects with subheadings will take less time to complete the task and will find it easier because they have structural clues with which to organize the individual standards.
3. Subjects will find ways to represent the standards other than using traditional hierarchies and this will be more prevalent in the condition without subheadings.

If hypothesis #1 is true, it would lend support to the idea that the subheadings make intuitive sense to people as demonstrated by their ability to create visual structures similar to the CCSS. If however, subjects with subheadings do not consistently arrange the standards into similar hierarchical clusters, it would suggest that perhaps the structure created by the subheadings is not, in fact, the most intuitive construction. If hypothesis #2 is true, it will further reinforce the idea that the subheadings are intuitive. However, if subjects without subheadings are able to complete the visualization in less time and with more ease, it would signal that perhaps the subheadings are not useful in structuring the concepts. Finally, if hypothesis #3 is confirmed, it will show that there may be alternate ways to represent the standards that may be more intuitive for some people. Conversely, if the majority of the subjects create a hierarchy similar to the CCSS, it would provide some confirmation that the standards are intuitively organized.

Of course there may be a variety of reasons that people graphically represent the standards in different ways, including their level of familiarity with the CCSS, their familiarity with 1st grade math or their prior training in constructing visualizations. I also examine these factors in this study.

General Description of the Experiment:

Primary Analysis: Subheadings Factor

In order to test my hypotheses regarding the influence of subheadings on the organization and graphic visualization of CCSS, I set up a primary analysis with two conditions:

1) "*with subheads*": subjects create visualizations using index cards with both subheadings and individual standards.
2) "*no subheads*": subjects create visualizations using only index cards with the individual standards.

Using these conditions, which are defined by the presence or lack of hierarchical cues (with subhead vs. no subheads) as independent variables, I set out to measure three dependent variables:

1. *Graphic organization*: hierarchy; concept map; matrix; or no connection (coded based on categories identified after inspection of the data).

2. *Time to complete task* (measured during the task with a timer).
3. *Perceived difficulty of task* (as measured by self-evaluation along a Likert scale after the task).

In order to ensure that there were not significant differences between the groups in terms of prior knowledge with curriculum standards or 1st grade curriculum, I compared average pre-task self-rakings using a Likert scale for each of these dimensions.

There are many possible outcomes to these various scenarios. In the Subheadings Factor, there could be a variety of graphic visualizations created by the subjects. If significantly more subjects in the "with subheads" condition created hierarchical visualizations parallel to the CCSS, it would support my hypothesis. If however, the "no subheads" group created structures more consistent with the CCSS, it would cast doubt on my hypothesis. It is also possible that there would be no difference between the groups. Similarly, if the "with subhead" group completes the task more quickly and finds it easier, my hypothesis that the structural clues help people organize the standards would be reinforced. However, it is also possible that there are alternative explanations for why people create different graphic visualizations that have nothing to do with the CCSS. For example, perhaps some people are visual thinkers or perhaps some people tend to thing in more structured ways that correspond to hierarchical representations.

Secondary analysis: Visualization Factor

In a secondary analysis, I examined whether students enrolled in a visualization class created different types of graphic visualizations than other students. I re-analyzed the same data used in the Subheading Factor but with the following two conditions / independent variables:

1) *"Vis":* subjects enrolled in visualization class.

2) *“No vis”:* subjects not enrolled in visualization class.

The Visualization Factor could show that people taking a visualization class tend to organize information differently than those not currently taking such a class. One argument would be that they are better at creating visualizations due to recent training. Conversely, it could be argued that the “vis” subjects were less creative because they were limited by what they were taught in the class. Again, it is possible that there is an alternate explanation. Perhaps people who tend to visualize information in more complex ways are also more likely to enroll in a class on visualization.

Methods

Participants:

Twenty undergraduate and graduate students at Stanford University participated in the study. Students volunteered to participate in response to a sign-up sheet passed around before a Visualization class or in response to an email request sent to students in the Learning, Design and Technology (LDT) masters program. Of these 20 volunteers, one graduate student and one undergraduate student participated in a pilot study and their results were not included in the findings. Of the 18 remaining participants, 12 were enrolled in a Visualization class (“vis”) and six were not (“no vis”). Within each of these subgroups, participants were randomly assigned to either the condition that included subheading information (“with subheads”) or the condition without subheadings (“no subheads”).

Materials:

The subjects in the "with subheads" condition were provided with a set of 12 white 3x5 index cards. Each card had either a Subheading or a Standard from the 1st grade math CCSS taped onto the card. Each card also had a symbol in the upper left corner of the Subheading or Standard. These symbols were added so participants could represent the card using the symbol when creating their visualizations. The subjects in the "no subheads" condition were provided a set of 9 orange 3x5 index cards. Each card had a Standard from the 1st grade math CCSS taped onto the card and a symbol in the upper left corner (see Appendix A for examples of cards).

Each subject was also provided with a worksheet to create their visualization. At the top of the worksheet were two statements related to familiarity with curriculum standards and 1st grade math. Participants were asked to rate these statements based on a 5-point Likert scale (Stongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree). In the center of the worksheet was a large rectangle where participants could create their visualization. On the back of the worksheet was a follow up statement to measure perceived difficulty of the task (also on a 5-point Likert scale): Worksheets were identical for both the "with subheads" and "no subheads" conditions (See Appendix B for example of worksheet).

Design:

Before the task was presented, each participant was asked to rate his or her familiarity with curriculum standards and 1st grade math. I also recorded whether or not they were enrolled in the EDUC 218 visualization class.

Each participant was in one of two conditions. They were either in the "with subheads" condition and were given the set of 13 white index cards or they were in the "no subheads" condition and were given the set of 9 orange index cards. All participants were given identical worksheets.

The study was an exploratory design with two factors. The Subheading factor reflected the amount of structural information provided ("with subheads" vs. "no subheads"). Dependent measures included: the type of graphic organization (hierarchy; map with interconnecting relationships; matrix; or picture with no connection between concepts); average time to complete the task; and perceived difficulty of the task. The second factor, Visualization, reflected whether students were currently enrolled in a visualization class ("vis") or not ("no vis"). Dependent measures were the same as in the Subheadings factor. (see Figure 1 for set up of dependent and independent variables across factors.)

Figure 1: Set up of Dependent and Independent Variables Across Factors

Subheadings Factor

	With subheads	No subheads
Type of Graphic		
Time to complete task		
Perceived difficulty of task		

Visualization Factor

	Vis	No vis
Type of Graphic		
Time to complete task		
Perceived difficulty of task		

Procedure:

All participants completed the task individually. Participants were given a worksheet and were asked to rate the following two statements on a 5-point Likert scale: 1) "I am familiar with or have used curriculum standards." 2) "I am familiar with or have experience with 1st grade math curriculum." In order to create a shared understanding of both the definition of visualization and the mission of the CCSS, the following prompt was shown to the participants and read aloud:

> According to Wikipedia:
>
> > **Data visualization** is the study of the visual representation of data, meaning "information that has been abstracted in some schematic form, including attributes or variables for the units of information".
> >
> > According to Friedman (2008) the "main goal of data visualization is to communicate information clearly and effectively through graphical means. (Wikipedia, n.d.)
>
> The Mission of the Common Core Standards is to: "provide a consistent, clear understanding of what students are expected to learn, so teachers and parents know what they need to do to help them." (Common Core State Standards, n.d.)

Pilot study: The first participant was given a set of white cards with the entire set of CCSS subheadings and standards for 1st grade math (a total of 36 cards). It quickly became clear that this was an unwieldy number of cards to sort and that it was extremely difficult for the subject to remember all 36 symbols in constructing and connecting the visualization. Based on this observation, I reduced the number of cards to 28 for the next participant. This second participant was given the 28 cards, but this was still unwieldy, so the cards were further reduced to a set of 12 white index cards for the "with subheads" condition and 9 orange cards for the "no subheads" condition. Because these first two participants were given a different number of cards than the rest of the participants, their representations were considered part of a pilot study and were not included in the results.

Regular study: The remaining 18 participants were given either the set of 12 white index cards "with subheads" or the set of 9 orange index cards "no subheads". These subsets of cards represented one Subheading from each of the four Critical Areas with its corresponding Standards. The following prompt was shown to the participants and read aloud:

> What I would like you to do is create a visualization of the common core standards on this sheet of paper. Here are cards with a sub-set of the common core standards. You can use these cards to organize your thoughts and when you are ready to create your visualization, you can use the symbol on the card so you don't have to write out the entire standard. For example, if you wanted to put this card on your visualization, you would just write the symbol '@'. These symbols are used only for convenience and the purpose of the study is not to test your ability to remember the symbols, so please feel free to add whatever prompts you would like in your visualization to help you organize your thoughts and ideas. If you need duplicate cards or if you feel you need additional cards to create your visualization, you can use these (show stack of extra cards and paper).

Participants were also told verbally, "This study is designed to take 10-15 minutes, but there is no time limit." Although there was no time limit, I did record the time using the stopwatch on my phone.

Participants laid the cards out on the table and then created their visualization on the worksheet. Some participants used the extra paper to draw a rough draft before transferring their visualization to the worksheet. No participants opted to use additional index cards. When they were finished, they let me know and I stopped the timer and recorded the time. I then asked them to turn the paper over and rate the following statement printed on the back of the worksheet using a 5-point Likert scale: "This was a challenging task." I thanked them for their participation and debriefed them on the study. I told them it was an exploratory study to see how people visualized the CCSS. I also told them there were two conditions: with the CCSS subheadings or without CCSS subheadings.

Coding:

The set of graphic representations created by the participants were sorted and coded based on patterns emerging from the data in terms of the types of connections represented. The following coding system was used (categories are considered mutually exclusive):

1=Hierarchy: Top down organization or groups with one-to-many relationships.

2=Matrix: Organized on a grid with both axes labeled.

3=Map: Items connected by either: one-to-many AND many-to-one relationships; OR many-to many relationships.

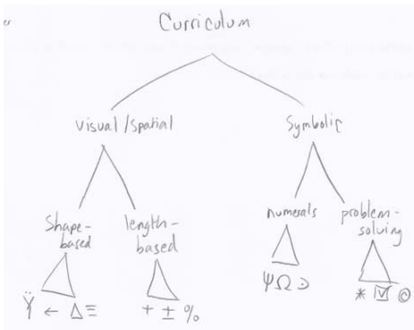
4=Picture only: Uses pictures to represent concepts, but does not connect them.

(see Figure 2 for sample graphics in each category)

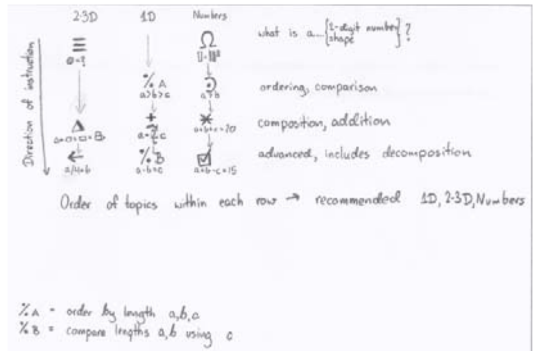
I tried to establish inter-rater reliability by asking three additional raters to code the data. I asked the first rater to create her own rating system of the pictures. She created a similar system to mine (hierarchy, interconnections, matrix, no connecting structure) and had 83% agreement with my categories. The additional raters were asked to code the data given my definitions of the categories. The agreement was 56% with the second rater and 83% with the third rater. I was especially concerned with the low 56% agreement with the second rater. The primary areas of disagreement were with the identification of matrix items and with hierarchy vs. map distinctions. In future experiments, I would try to correct this by spending more time establishing a common understanding of the coding scheme.

Figure 2: Sample graphics from each category

1: Hierarchy example:

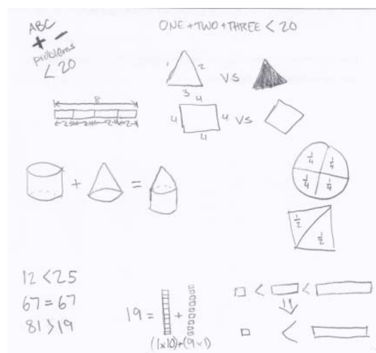


2: Matrix example:



3: Map example

4: Picture example

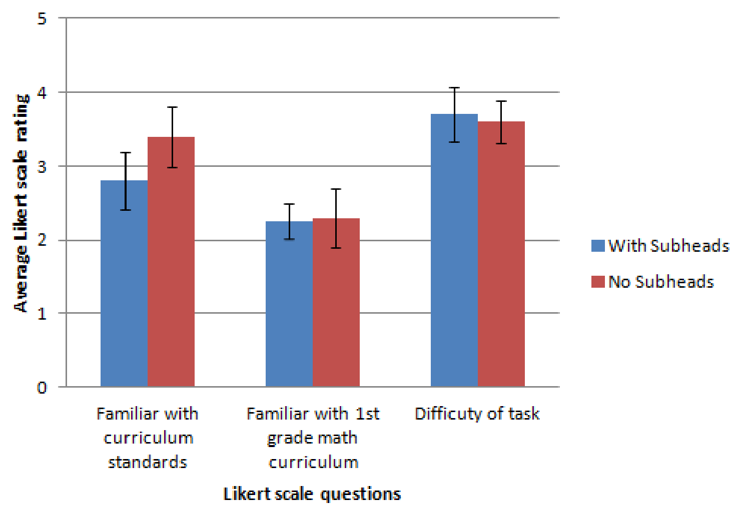


Results:

Subheadings Factor:

The results showed that the conditions were closely matched across the three Likert-scale rated questions (see Figure 3 for summary table). The “no subheads” condition rated themselves slightly higher than the “with subheads” group on familiarity with curriculum standards. Both conditions rated themselves similarly on their familiarity with 1st grade curriculum. After creating their graphic representations, both groups rated the difficulty of the task and there was not a significant difference between the two conditions.

Figure 3: **Subheadings Factor: Average Likert Scale Ratings by Question**



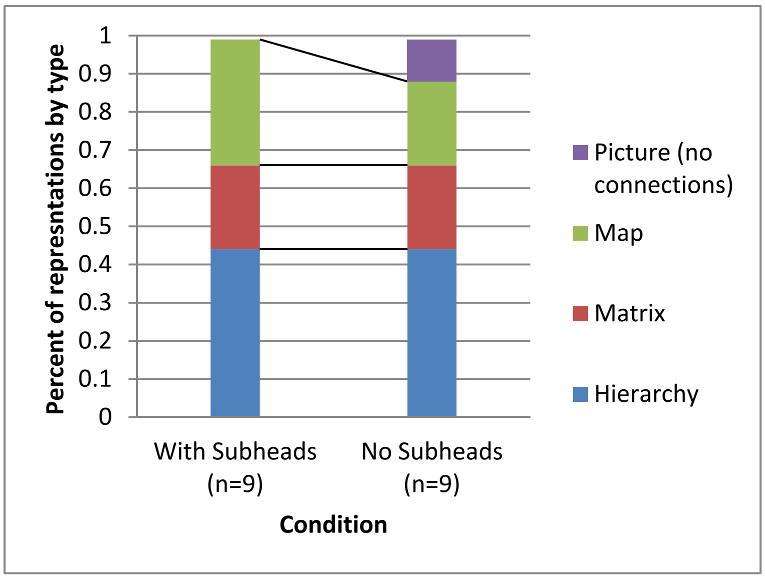
Results based on the type of graphic organization are presented below in Figure 4.

Results addressing hypothesis 1 ("with subheads" would create more hierarchical representations): 44% of subjects in both conditions created hierarchies, so there was no difference between groups. The hierarchies in both groups generally mirrored the hierarchical structure of the standards as presented in the CCSS.

Results addressing hypothesis 2 ("with subheads" would take less time and find the task easier): The amount of time participants took to complete the task ranged from a minimum of 3 minutes and 45 seconds to a maximum of 30 minutes and 30 seconds. The average completion time for the "with subheads" condition was 13.8 minutes, while the "no subheads" group averaged 11.6 minutes. On the surface, this looks like the opposite of what I predicted, but with a t-test result of .5, the difference is not significant. In addition, there was virtually no difference in the average rating of difficulty as seen in Figure 3 (3.7 vs. 3.6).

Results addressing hypothesis 3 (subjects will find ways to represent the standards besides hierarchies, especially in the "no subheads" condition): Subjects did represent the standards in non-hierarchical ways, but both conditions created the same percentage of hierarchical visualizations (44% hierarchies in both conditions). 56% of subjects graphically represented the CCSS in ways other than hierarchies which does support the first part of hypothesis #3. In terms of differences between the conditions, one subject in the "no subheads" condition created a picture without connections, but otherwise the two conditions were similar in the number of representations they created in each category (see figure 4).

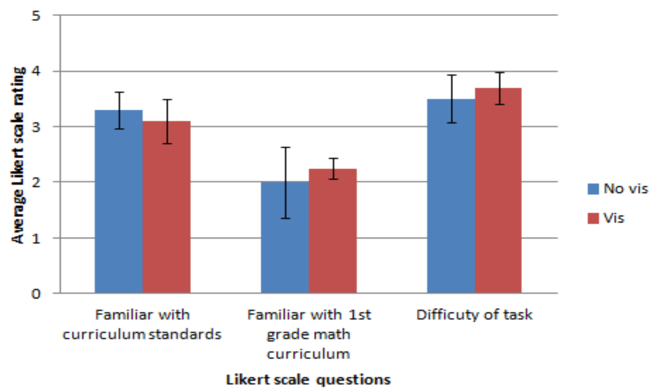
Figure 4: Percent of visualizations by type within each condition—Subheadings Factor



Visualization Factor:

There were no initial hypotheses related to the Visualization Factor because it was exploratory—I decided to examine this factor after the study had already commenced. Participant visualizations were placed into two conditions ("vis" or "no vis") based on whether or not they were currently enrolled in a visualization class (in which I was also currently enrolled). The results showed that the conditions were fairly similar across the three Likert-scale rating questions (see Figure 5 for summary table).

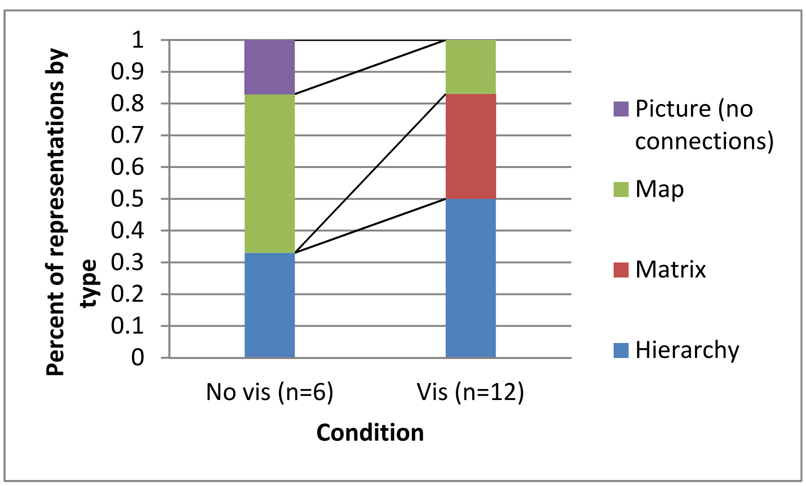
Figure 5: **Visualization Factor: Average Likert Scale Ratings by Question**



In regards to the type of visualizations created, there were some interesting differences (see Figure 6). 50% of the participants in the "vis" condition created hierarchies as opposed to 33% in the "no vis" condition. In addition, 33% of the participants in the "vis" condition created matrices as opposed to 0% in the "no vis" condition. The one visualization that had no clear connections between standards was in the "no vis" condition.

The "vis" participants took slightly longer to complete the task (13.8 minutes as opposed to 10.6 minutes).

Figure 6: Percent of visualizations by type within each condition—Visualization Factor



Discussion:

Subheadings Factor:

Subjects in both conditions created a variety of different representations. Hierarchies represented 44% of the visualizations in both conditions. The presence or absence of subheadings did not seem to affect whether or not subjects were able to organize the standards in a hierarchical fashion. In addition, both groups created hierarchies consistent with the structure of the CCSS. Contrary to my hypothesis that the subheadings would help cue subjects in the "with subheads" condition to create more hierarchical structures around the subheadings, the standards seem to intuitively fall into these types of hierarchical categories for many participants in *both* conditions. This lends support to the question asked at the beginning of this paper: "Are the standards written in such a way that they can be intuitively understood."

The "with subheads" group took slightly longer to complete the task, but they also had more cards because of the subheadings (12 cards as opposed to 9). The extra time to sort the cards with subheading and to draw them into the visualization could explain why the task took longer, on average, in this condition.

On one hand, many subjects in each condition created hierarchical representations (44%). On the other hand, there was a wide variety of creative alternative visual representations of the CCSS. Even within the hierarchical category, there was a range of creative representations with many participants adding supplemental information to their drawings such as their own labels for headings and subheadings. Representations also contained varying levels of depth. For example, some drawings just had two levels, while others had three or more levels. In addition, 56% of subjects created graphic representations other than hierarchies. The matrices and maps also had varying levels of creativity and complexity. This would suggest that there are, in fact, many ways to visualize the CCSS.

Due to the variability in both the complexity and the creativity of the representations, it was difficult to assign the drawings to distinct categories. Indeed, there were inconsistencies when different raters were asked to code the data. Although it is interesting to examine the visualizations using the framework of hierarchies, matrices, maps, and no connections, there are many other possible ways to categorize the representations and thus, many alternate interpretations of the data.

Finally, there are several alternative interpretations of these results. One possible interpretation could be that people create different graphical representation based on their level of artistic ability. Perhaps more artistic people are inclined to draw more creative designs to represent the concepts. Another possibility is that people will create representations based on how they think and structure information in their minds. For example, perhaps linear thinkers are more likely to create hierarchies; more complex thinker will create matrices; and spacial thinkers will create maps with multiple interconnections.

Visualization Factor:

Although this factor was identified after the study had commenced and had an unequal number of participants, it is interesting to compare the visualizations of participants in the two conditions. In particular, none of the "no vis" participants created matrices, while 33% (4 participants) from the "vis" condition created matrices with labels on both axes. As a student enrolled in the visualization class, I know that the instruction included use of matrices. It is possible that participants in the "vis" group were influenced by the instruction in the class to create these types of graphical representations.

An alternate interpretation would be that students who choose to take a class on visualization, tend to think in more complex visual ways, which is what attracted them to the class. Another alternate interpretation could be that students enrolled in a visualization class have an outside interest in common, such as math, which could explain the tendency to use matrices to represent pieces of data.

General Discussion

The Common Core State Standards Initiative has set ambitious goals of establishing shared standards for grades K-12 in order to prepare students for careers or college. As curriculum and instruction are increasingly focused around these standards, it is important that they are intuitive to understand, that they can be successfully implemented in the classroom, and that student achievement can be measured using these standards as benchmarks. This study attempted to examine whether the standards are intuitive by having subjects create graphical visualizations of the standards. While 44% of participants created hierarchical representations that paralleled the CCSS, many created alternate types of representations. The observation that 44% of representations were similar to the CCSS, provides some support for the argument that these standards are intuitive. For the other 56% of the representations the interpretation is less clear. Perhaps these people do not intuitively view the standards as a hierarchy, but if they saw the standards in hierarchical form (as they are presented on the CCSS website), these people would be able to make intuitive sense of them and use them to guide learning and instruction. But what if the majority of people think differently than the creators of the CCSS or if the best way to represent the standards is not in hierarchical format? Would that make understanding and internalization the standards more challenging?

One interesting aspect of this study was the impromptu comments participants made after completing the task. Several thought this would be a good exercise for teachers to help them understand and construct the standards in a way that was consistent with their teaching style or so they could internalize their own conception of how the standards fit together. Others commented on how this would be a good exercise for students, so they could visualize the expectations outlined in the standards in a way that made sense for them. Additionally, once students made their own outline, they could track their progress through the curriculum as they attained mastery on each standard.

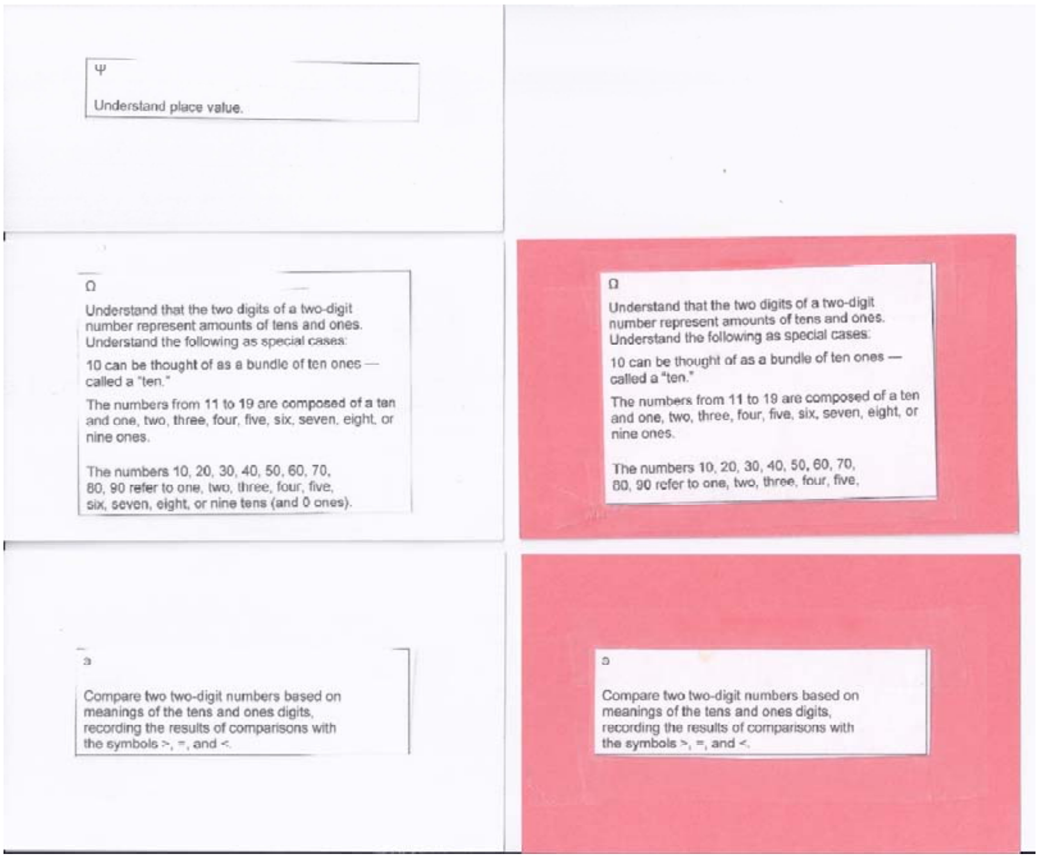
Exploratory studies using unique graphical data can be challenging to analyze. But now that we have some data on how people view the CCSS, it would be useful to vary some aspects of the study in order to dive more deeply into the question of whether the CCSS are intuitive and then to move on to address the questions of implementation and assessment. Because the standards have far reaching implications for our education system, these questions are worth exploring. For example, using alternate coding schemes that would result in higher inter-rater reliability could help improve the validity of the study. In addition, having a second group of subjects rate the intuitiveness of the visualizations created in this study and then having a third group create lesson plans based on the top-rated visualization would further illustrate the utility of specific types of designs. Another variation might involve collecting data from types of participants likely to utilize the standards (i.e. teachers, parents, students). Controlling for variations in areas such as artistic ability and instruction in the use of graphic representations might help isolate the variables that contribute to different types of representations. And selecting different independent variables, such as visualizing math standards across different grades would be informative. Finally, asking participants to construct the visualization with a specific purpose in mind would help address the question of how to represent the CCSS so that they are intuitively understandable for others. For example, would visualizations vary based on whether participants thought they were creating a representation for: a teacher; a student; a parent; or a presentation at a school board meeting?

Even the current design could be taken a step further. For instance, many of the participants expressed a feeling that they understood the standards better after the exercise. One participant told me later, “I’m still thinking about how they go together.” If this is true and doing this exercise stimulates deeper and more prolonged thought about the standards, would subjects be able to design better lessons plans or more coherent curricular strands after creating their own interpretation of the standards? If students did this exercise, would they feel more invested in reaching the benchmarks outlined by the standards? Perhaps this experiment could be used in teacher training or professional development.

States throughout the country are interpreting and implementing the CCSS. These standards must be clear and intuitive if we intent to use them to guide and gauge student academic achievement. Although graphical designs can be difficult to quantify and analyze, examining the types of representations people create can help us understand how people visualize the CCSS concepts. In addition, the very exercise of creating the visualizations seems helpful in getting people to think about the standards in deeper and more interesting ways. This study shed light on the different types of visualizations people create to represent the CCSS. Hopefully future studies will be able to provide additional insights on how educators can view the CCSS in a ways that facilitate and guide effective instruction.

Appendix A

Sample index cards for different conditions. White cards used for “with subheads” condition (i.e. “Understanding place value”) and orange cards used for “no subheads” condition.



Appendix B

Participant worksheet:

(Front)	(Back)
1. I am familiar with or have used curriculum standards (circle one): Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree 2. I am familiar with or have experience with 1st grade math curriculum (circle one): Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree	This was a challenging task (circle one): Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree

References:

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Education Northwest. (n.d.). *Common Core State Standards History*. , Retrieved from http://educationnorthwest.org/resource/1280 .

Wikipedia, (n.d.). Retrieved 11/22/2011 from http://en.wikipedia.org/wiki/Data_visualization .