Visualizing The Flow And Usage Of Curricular Components In An Online Curriculum Planning And Teaching Tool

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VISUALIZING THE FLOW AND USAGE OF CURRICULAR COMPONENTS
IN AN ONLINE CURRICULUM PLANNING AND TEACHING TOOL

by

KIRUN AGARWAL

B.S., University of Colorado, 2011

A thesis submitted to the
Faculty of the Graduate School of the
University of Colorado in partial fulfillment
of the requirement for the degree of
Master of Science
Department of Computer Science
2013
This thesis entitled:
Visualizing The Flow And Usage Of Curricular Components In An Online Curriculum
Planning And Teaching Tool
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The final copy of this thesis has been examined by the signatories, and we
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IRB protocol # 11-0067
Agarwal, Kirun (M.S., Computer Science)

Visualizing The Flow And Usage Of Curricular Components In An Online Curriculum Planning And Teaching Tool

Thesis directed by Professor Tamara Sumner

The Internet can be useful in supporting teacher planning and instruction. However, there is no way for teachers to know if they are progressing through the curriculum at an appropriate pace. The focus of this thesis is exploring the use of visualizations in aiding teacher planning and instruction. Visualizations were created using Processing, an open source programming language and environment. Data from the Curriculum Customization Service was used to display curricular flow. The visualization contains three layers representing the group’s flow, the ideal flow, and an individual user’s flow. These layers show the flow through the units of the curriculum. Another graph can be displayed by hovering over lines in the layered graph, which shows the most popular concepts among users. The visualizations were tested by asking five users to complete three tasks using the visualizations. All five users were able to complete the tasks though some had more difficulty than others, showing that while many improvements are needed, the visualizations do allow users to see their curricular flow and make comparisons.
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CHAPTER I

INTRODUCTION

The Internet can be useful in supporting teacher planning and instruction. However, it is difficult for teachers to know if they are progressing through the material at an appropriate pace. Teachers have no way to see what other teachers are doing unless they are able to contact them. It is also difficult for them to compare how they are doing compared to the ideal pacing for the curriculum.

The focus of this thesis is exploring the use of visualizations in aiding teacher planning and instruction. The context of the research is drawn from data from the Curriculum Customization Service (CCS) which will be used to create the visualizations, the aim of which will be to examine how visualizations can enable useful displays of data that allow self-reflection and group analysis. Specifically, the visualizations produced will focus on the concept of “curricular flow”, how this flow relates to the use of the CCS and how flow might vary between teachers, schools, and districts. While there is a wide variation in flow amongst teachers and the expected flow through the materials, visualizations may still yield valuable insights that would not be possible without the use of tools like the CCS.

1.1 Curriculum Customization Service

The Curriculum Customization Service (CCS) is an online resource for science teachers to aid in their planning and instruction. The system is designed to allow teachers
access to curricular materials from publisher materials such as digital versions of book chapters, to online digital resources originating from high quality science repositories that connect with the goals and objective of the particular subject of study. Detailed descriptions of the CCS are available elsewhere [20, 21, 22], thus the system description in this thesis will focus primarily on the structural components of the CCS that form the basis of our visualizations. The CCS is composed of several different curricula such as “Physical Science”, “Earth Systems”, etc., that address grade level appropriate materials and resources that are divided into a hierarchy of “units”, “chapters” and “concepts”. “Units” contain several “chapters”, which are divided into “concepts.” One of the unique features of the CCS is that it is instrumented to track user actions within the system, and along with a number of other data points, stores the unit, chapter, and concept of all resources used within the CCS. These data points will later provide the basis for the data visualizations described in Chapter 2.

The CCS includes collaborative features which support sharing and social activity, which are designed to encourage further use and participation in the system. As seen in online collaborative communities that are intended to provide social benefit to their end users many still fall short of their goal to support full engagement and participation. For example, in a study of the online community ALCOT (A Learning Community of Teachers) [1], it was found that despite encouragement, many teachers did not fully engage with or participate in the community. In ALCOT, teachers were encouraged to post or blog to the community, and were graded on their participation. Feedback was collected through interviews to determine how teachers were using the resources available within ALCOT. Though posting behavior increased over time, teachers did not utilize the blogging features of the system, even though they did post responses to the group leader’s blog. Many teachers believed that only the group leader was allowed to write a blog [1], and had they
been presented with visual information about how they were using the system, they might have engaged the blogging feature, which they apparently did not otherwise understand [2].

It is a well-known phenomenon that there is a large variance in the amount of time teachers spend on each unit. More time is spent on earlier units, which leaves less time for later units. By showing teachers the ideal pacing of the curriculum and how their own pacing compares, teachers may be able to adjust their own pace to keep up with the recommended pacing and avoid falling behind.

Administrators can also benefit from visualizations of teacher activity. District pacing guides can often be too ambitious. If administrators can see which parts of the pacing guide are too difficult for teachers to keep up with, they can make adjustments to the recommended pacing to make it easier for teachers to teach all of the necessary material.

1.2 Use Cases, Research Questions & Methodology

Visualizations of how teachers are using the various curricular components within the CCS would ideally allow support for two important use cases. First, end users of the CCS (teachers) would be able to see their own flow through the curriculum. By doing so, they could reflect on their own use of the curriculum or they could compare their flow to that of other teachers in their school or district. Recent studies have shown that visualizations can assist people in self-monitoring and thus help them become more aware of their own behavior [4]. Such visualizations even have tangible impacts on behavior if they can show end users how their performance can be improved [5]. Furthermore, by comparing their flow to that of their school or district’s ideal flow or “ideal pacing”, CCS users might benefit from seeing their pacing compared to the ideal pacing, and adjust their
instruction, seek additional resources or assistance if they notice they are falling behind, or even slow down if they do not appear to be spending enough time on certain concepts.

A second major use case would be applicable to administrators or high level personnel interested in the impact online curriculum-support systems have on their teachers. Such users might be able to look at the aggregate curricular usage patterns of teachers in their own school or district to that of the ideal pacing for that curriculum. Additionally, they might also look at how other schools or districts compare to how their own district is using a particular curriculum. Research has shown that teachers have a large impact on student achievement, and that students scored higher average scores in math and science if their teacher was rated high in teacher effectiveness and had high principal ratings [3]. The ability to visualize the pace at which teachers progress through the curriculum may be one way of many ways for administrators to link curricular materials to teacher effectiveness, and may also be valuable in linking such pacing data with formative assessment data.

Building on these use cases, this thesis aims to answer three key questions:

1. What kinds of visualizations can be made from the current CCS data that show the use of the curricular components of the CCS to various stakeholders with different visualization needs?
2. How will teachers and high-level administrators react to the proposed mockups that develop as a result of the first question?
3. What was the impact of the proposed implementation and how might they be improved for future integration and study within the CCS?

The aim of this thesis is to develop prototypes of visualizations using data from the CCS and present them to potential users such as teachers and administrators for feedback.
From the information gathered, I will reflect on whether or not the data and tools I used addressed questions 1 and 2 adequately.

In order to answer these research questions, the CCS data will be used to learn how visualizations can show the flow of teacher planning throughout the school year. The data will also be used to learn if visualizations can be used to understand variability between individuals, groups (such as schools or districts) and compare these to the ideal pacing. These visualizations may also be useful for school or district administrators to understand how teachers are (or are not) following the ideal pacing for their curriculum.

Once mockups are developed to display this information, they will be presented to a few teachers and administrators to record their reactions to the visualizations and gather feedback. Teachers and administrators may have different reactions depending on their needs. For example, teachers may want to see their own flow and compare it to that of others, while administrators may instead want to compare the flow of a group of teachers to the ideal pacing.

After feedback has been received for the prototypes, it I will reflect on what kinds of new information are needed to produce more useful and meaningful visualizations, and also evaluate the strengths and weaknesses of the visualizations and the tools used to create them. Finally, I will reflect on the technical architecture used for my prototype and discuss the process by which the data and visualizations were structured and developed.

1.3 Related Work

Many visualizations have been created to help users visualize their own behavior and compare it to that of others. One area in which such visualizations have been helpful is fitness. Research has shown that personalized information about one’s fitness is beneficial.
Many people are busy and only have time for informal exercise routines. It is difficult to track how much they are exercising and set goals. Visualizations are often used to create structure, accountability, motivation, and feelings of success. However, they can also be demotivating if users suffer temporary setbacks. Many people can become discouraged if they do not follow a linear path to success. Unfortunately, most people do not feel they have been successful in managing their weight and fitness. Therefore, frequent displays of fitness metrics can cause users to feel anxious. Visualizations need to coach and support and can be especially useful when they encourage self-reflection. They can even be used as a diary and keep track of what the user has been doing over a period of time [6]. Visualizations that encourage users of the CCS to reflect on their own performance and act as a diary of the school year may help teachers improve their performance.

Fitster is a tool meant to reduce sedentary behavior by helping busy people exercise. A four-week study was conducted with six full-time graduate students to determine their needs and motivations. The participants wore pedometers and recorded their results on a community blog. Mockups were created and the design of Fitster was finalized using feedback from the participants. Fitster allows users to upload their step counts and displays them in a bar graph. Users can also see their friends’ average daily step counts and compare their progress. This allowed for teamwork and competition, which increased accountability. Users were more likely to engage in physical activity. Users reacted positively to the system, but all of the participants of the study were full-time graduate students. A wider variety of users would be needed to see if Fitster would be useful for other demographics [7]. Fitster shows that people can improve their own performance by using visualizations to compare it to that of others. By cooperating and competing with others, people were more likely to engage in physical activity.
Visualizations have also been used for other types of data. Many Eyes is a website for creating and discussing visualizations. Thousands of visualizations were created on the site in the eight months after its launch. However, little was known about the activity on the site. Many Eyes allows users to upload data, create and publish visualizations of that data, and discuss the data and visualizations. In a study of the users of Many Eyes, users of these visualizations have said that they give new insight into the data. They also reported that visualizations help users engage with the data and make previously inaccessible domains of knowledge accessible. This study reveals that visualizations allow users to engage with data in a new way [2]. Even though users of the CCS might have an idea of how they are progressing through the curriculum, a visualization might give them new insight into their own activity, which could encourage self-reflection.

Another area in which visualizations have been used for self-monitoring is web use. Many businesses use information provided by users to profile them and target advertisements. Unfortunately, information about users is sometimes inadvertently released by these businesses. Many users are unaware of these privacy risks. Self-monitoring would allow users to be more aware of what information they are releasing. Most users in the study found it useful to view their past search queries to see what information was being revealed [4]. This study also shows that visualization can make people more aware of their behavior and encourage self-reflection.

Self-monitoring has also been shown to be helpful in friend recommendation in social networks. SFVis (Social Friends Visualization) helps users explore different types of recommendations in an interactive way. It uses a hybrid of content-based filtering and collaborative filtering to recommend friends. Content-based filtering uses information provided by the user to match profiles. Collaborative filtering instead relies on user ratings of items to make predictions about the user's interests. It uses social tags to create a tag
network. From the tag network, a tag hierarchy can be created. People in the social network are matched to the tag hierarchy. Tags assigned to the same items by different users indicate a semantic relationship between them and can be linked together to form tag networks. These networks are shown in a circular layout. SFVis also shows why the recommended people are similar to the center user. The study concluded that SFVis has the potential to enhance user’s awareness of their social networks and help them seek friends in new ways [8]. This visualization shows that visualizations can be used to make users more aware of others in their community, which may even encourage interaction between similar users.

Visualizations have also been used to help users get more sleep by making them more aware of their sleep habits. ShutEye is a mobile phone application that displays sleep recommendations. It allows users to compare their current habits to the habits that are recommended by sleep experts to minimize daytime sleepiness. Even people who have knowledge of good sleep habits might have sleep problems because they do not remain aware of their own habits. Most of the participants of the study felt that ShutEye made them more aware of their sleep habits. They also had changed their caffeine consumption and reported less daytime sleepiness [5]. Similar to ShutEye, a visualization of the CCS data may help teachers remain aware of their curricular flow.

Most users said they found ShutEye easier to use when they thought of its rules as recommendations rather than hard rules [5]. This study shows that people can benefit from a visualization that allows them to compare their performance to an ideal performance. In this case, users compared their sleep habits to the recommendations given by ShutEye. While they didn’t do everything suggested by the application, they were able to make some changes to improve their sleep habits such as changing their caffeine consumption.
There has also been work in task visualization. Bloom displays an email inbox as a vase of flowers. It uses existing email starring systems to add flowers to the vase. As an email is starred, a new flower is added to the vase. Each bloom is color-coded based on four different tasks: Money In/Out, School, Personal, and Informational. Important emails can be accessed easily while unimportant ones are not displayed. Once a task is done, the flower is plucked off. This display allows employees to complete their work without distraction and achieves a high level of engagement [9]. Visualizations such as this can simplify complex tasks and make it easier for people to see how they are progressing. Visualizations created from the CCS data must present information in a simple way, without being visually overwhelming.

Task visualization has also been used in emergency evacuations. The research was conducted with the project OASIS (Open Advanced System for Improved Crisis Management). Because of the large amount of information that needs to be presented, several different views were used, including a summary view, a map display, a source-destination matrix, and a Gantt chart showing the distribution of trips over time. Because the visualization has been split into several simpler views, it becomes easier to use and understand [10]. Visualizations created from the CCS data might also benefit from being split into two or more views if there is too much information for one view.

Some types of visualizations can be more effective than others. In the self-monitoring of web use study, it was found that users preferred certain visualizations to others. Most (55%) found the Windows Explorer-like visualization to be the most useful. However, some preferred the bubble chart (31%) while others preferred the Seesoft view (14%). The users who preferred the bubble chart found it more aesthetically pleasing and thought it was a faster way of viewing category activity. People who preferred the explorer view thought it was easy to use and organized in a useful way. They found being able to see
the overall categories with the option of viewing a more detailed list useful. Many users felt the bubble charts wasted space. Because the most popular visualization received only 55% of votes, the study concluded that several different options should be included [4]. Because the CCS data would allow for many different types of views, it may be useful to try making several different designs before deciding which view is the most useful. It may also be useful to give the user a summary view and an option of a more detailed view.

In a study of students in introductory programming classes, it was found that animations could help students understand even complex algorithms more easily. However, the students’ learning styles affected how effective the animations were. Students were surveyed using the Visual-Aural-Read/Write Kinesthetic (VARK) analysis, which provides users with a profile of their learning preferences. Each class that was tested contained students with different learning preferences. For example, in CS1 and CS2, many students were kinesthetic learners, which means they need more hands-on experiences [11]. In another study, perceptual speed (PS) was found to influence what sorts of visualizations were most effective. One visualization used colored boxes and the other was a radar graph. Users with higher PS preferred the colored boxes to the radar graph while users with lower PS preferred the radar graph [12]. These studies also show the benefits of presenting users with several different views. Different people might react differently to the same visualization.

While there has been much work done on visualizations comparing individual and group behavior, there has not been much work done visualizing teacher behavior in an online system. There is potential for unique and interesting behavior in this setting. Unlike many other communities, such as people trying to improve their physical fitness, teachers are affiliated with schools or districts, which affects their behavior. Depending on their school or district, teachers use the CCS differently. Different districts may have a different
ideal pacing or flow through the curriculum, which will affect the behavior of teachers. Teachers from different districts may have completely different curricular flow even if they are all following their districts ideal pacing. This presents a unique challenge in comparing the behavior of different users. In other types of groups, it may be useful to compare everybody in the group together, but teachers might benefit more by being compared by school or district.

Another unique challenge presented by working with the CCS is that there are different types of users. Some of the users are teachers, while others are administrators. Teachers and administrators may need different visualizations depending on the type of information they are looking for. Administrators might find a visualization comparing different districts more useful than teachers would, for example. Therefore, teachers and administrators may have different reactions to the same visualization. It will be necessary to display information that is useful for both teacher and administrators. It may also be useful if users could choose which information to display and which information to hide in order to serve their needs.

There have been several studies done on task visualization, but in general they show an individual’s progress toward completing the tasks without comparing it to others working toward completing the same task. For some tasks such as managing an email inbox, there doesn’t seem to be much benefit in comparing progress to others since other people have different amounts of email and different goals. The CCS presents a unique situation, where many people must complete similar tasks, in a similar way, with similar goals. Therefore, it is possible to compare teachers’ progress towards the goal of completing the curriculum in one school year.
CHAPTER 2

VISUALIZATION

The first research question of this thesis is designed to address the creation of a visualization that allows various modes of CCS usage characteristics (or “flow) over time. As part of these visualizations, it is hypothesized that three modes are befitting to teachers: (1) teachers might see their own usage and (2) they might see that usage compared to others’ with in their own school or district, and (3) they be able to see their own flow relative to the “ideal” curricular flow as set forth by the suggested pacing for the curriculum they are teaching. In addition to visualizations that support teachers, a final mode is aimed at administrators who hypothesize might desire to see the high-level progress teachers in their school or district are making within the curriculum and be able to compare that progress to the ideal flow at both the school, district and inter-district level. I will therefore develop visualizations in a prototype that will address each of these scenarios and apply the necessary user data that support them.

2.1 Visualization Layers

In order to allow users to make the kinds of comparisons addressed in the previous section, the visualization will be broken down into three layers as shown in Figure 2.1. The first layer shows an individual’s flow through the curriculum. The second layer shows the flow of a group (such as a school or district). Finally, the third layer shows the ideal flow,
which would be a district’s recommended curricular flow. These three layers are displayed in a single graph, so users can compare the three layers.

![Graph showing three layers](image)

**Figure 2.1: Graph showing three layers**

The first layer, showing an individual’s use of the CCS curricular materials, specifically shows when the user accessed each of the units and concepts. Similarly, the group layer shows an aggregate flow -- displaying averages over the CCS usage of many individuals. The final displays a district’s recommended curricular flow or ideal use of the curriculum, allowing end users to compare it to the individual or group flows. These three layers can be used individually to track individual or group usage, or they can be used together to make comparisons.

The individual layer is intended to be used mostly by teachers. Teachers can view their own usage and compare it to the recommended flow or the flow of other teachers in the same school or district. Through these comparisons, they might see if they are ahead of or behind in the curriculum, as compared to either the ideal pace or that of their peer teachers. Such information might be valuable, since if they notice a problem, they can make
potential pedagogical adjustments to accelerate their pace to match the ideal pacing.

Throughout the school year, teachers can monitor their own usage to see if they are making sufficient progress. The graph can also reveal if teachers are spending too much time on a certain unit, for example. Knowing and seeing this may make them more aware that they need to complete unit and move on, or in the case where there are additional challenges, for example with a class that is spending more time than expected, changes might be made to the class materials, pedagogy or in the case where the teacher needs help that exceeds their ability, such help can be recognized as necessary and provided quickly and effectively.

Administrators might also be able to use this layer if they want to monitor the performance of individual teachers, for example, to understand if clusters of students seem to be getting stuck with certain material, or even to understand if certain units are not being covered at all by teachers.

Since the aggregate layer makes it difficult to see issues that an individual teacher might be having, this layer becomes more valuable because it allows teachers to see what they are doing. Without a way to track how they are progressing, teachers may have difficulty knowing if they are progressing at a normal pace relative to what is considered ideal for the material they are covering. It also helps give teachers feedback on how they are doing which could motivate them to make changes to their instruction or take other action (e.g. seek additional help), if they think they can improve the outcomes. Finally, seeing such information, may act as a kind of “diary” for the school year that allows teachers to see their personal progress on the things they were doing throughout the school year.

The group layer is intended to be used mostly by administrators. They can compare the flow of the teachers in their school or district to the flow recommended by the district to see if teachers are keeping up with the suggested pacing of the curriculum. If teachers are
behind the expected pacing, the graph visualization might help reveal problems to administrators, perhaps sooner rather than later, so that appropriate interventions can be made. Since the group layer is an average of the usage of many individual users, problems many teachers had are visible while problems only a few individuals had are hidden. If many teachers are all having difficulty with the curriculum in the same place, it might be necessary to make adjustments to the curriculum or alternatively, the recommended flow may need adjustments. Teachers might be able to use this layer as well, if they are interested in comparing their own performance to other teachers in the same school or district. Since the group layer aggregates the usage of many individuals, administrators may see the general performance of all the teachers in their school or district at a glance. If all of the teachers are having a similar problem, it will be visible in the graph. Like the individual layer, the group layer can also act as a diary. If there are problems in the current school year, administrators can use the group layer as a reference while planning for the next school year.

The ideal layer is intended to be used by both teachers and administrators. Unlike the other layers, which can be used as a diary to keep track of usage, this layer is mainly intended to be used for comparison. Teachers can compare their own usage to the ideal. If they are behind or ahead of the ideal, they can adjust their instruction to the recommended pacing. Administrators can use the ideal layer to see if teachers in their school or district are moving through the curriculum at the advised pace. If there is a problem, the graph may help administrators catch it quickly and fix it before it gets worse. This layer is valuable because teachers can use it as a guide that they can refer to throughout the school year while administrators can directly compare it to the group performance. Combined with the individual layer or group layer, it acts as feedback for both teachers and administrators. They can see if they are doing well or if there is room for improvement.
2.2 Calendar

When the user first views the visualization, the user sees a calendar displaying the months of the school year as shown in Figure 2.2. The first month is September and the last month is May. The months are displayed in a 3X3 grid. Within each square, the most frequently accessed units for each month are listed. The most frequently accessed unit is displayed in the largest font at the top of the square, while less frequently accessed units are displayed in smaller font below. The units are shown in a darker font than the names of the months to make them stand out while the names of the months fade into the background. At the bottom right corner of each month’s square, there is a small image the user can click on to display the three layered graph. The calendar is intended to give the user a simple, high-level view of the aggregate curricular flow without overwhelming the user with too many details. Users can see the progress through the curriculum by looking at the most frequently accessed units each month. By clicking on the images, the user can get a more detailed view of the information displayed in the calendar.
2.3 Layered Graph

When the user clicks on the images in the month grid, a graph is displayed to the right of the calendar as shown in Figure 2.3. The graph shows curricular flow by showing when each unit was frequently accessed. A line is used to represent this. The start of the line is when the unit first started to be frequently accessed and the end of the line
corresponds to the end of its period of heavy use. Whether or not a unit is “frequently accessed” is determined by how many times a particular unit was accessed. If it was accessed at least fifty times during a week, it is considered “frequently accessed”. By the end of the school year, fewer people were using the system, so the threshold was lowered to thirty. There is a small square at the center of each line. Time is plotted along the x-axis, while the unit is graphed along the y-axis. The first unit is at the lowest position, while the last unit is at the highest. This method allows users to see progress through the curriculum. The higher the position of the line, the further into the curriculum the user or group is.

![DPS Earth Science Curricular Flow](image)

Figure 2.3: Three-Month Graph

This method also makes it easy to make comparisons. For example, if a user wants to compare his/her flow to the group as a whole, he/she can compare the positions of the
lines in each layer. If the lines in the individual layer are lower than the lines in the group layer, the individual’s pace is slower than the group’s. If the lines are higher, the pace is faster than the group’s. As the school year progresses, the lines should move toward the top right. If they don’t, it might mean users are not making progress, but could also mean that the units are not being covered in order. If there is some overlap between two or more lines, multiple units were being accessed by users at the same time.

In order for users to be able to compare the three layers, they must be displayed together in a single graph. To allow the user to easily distinguish between the layers, different colors are used for each layer. Red is used for the group layer, green is used for the ideal, and blue is used for the individual. These colors were selected because they are easy to distinguish from each other and clearly visible on the graph’s white background. By default, the group layer is selected, so users can see the information from the calendar in more detail. When a layer is selected, the lines in that layer are completely opaque to stand out. If the layer is not selected, the lines are more transparent to fade into the background. However, the user can still see them to compare with the selected layer.

The user can select different layers by clicking on the labeled boxes at the top right of the graph. When a layer is selected, an “X” is displayed next to the label. All of the layers can be selected or deselected. Multiple layers can be selected at once. This is intended to allow the users to compare the layers. For example, if the user wants to compare his/her performance to the ideal flow, he/she could select both the individual layer and the ideal layer. If the user just wants to focus on one layer, the others are still visible for comparison, but the selected layer is much more prominent.

Each graph shows a three-month period, one graph per row on the calendar. When the user clicks on the image for one of the months in the top row, the graph for the first three months is displayed. If the user clicks on an image in the second row, a graph of the
second three-month period is displayed. If a unit was never used very much during the three-month period, it is not included in the graph, which helps keep the graph as small and simple as possible. This allows users to find the information they need as quickly as possible because unnecessary information is not displayed.

There is also an image at the top right of the calendar with the text “See Full Graph" to the left of it. If the user clicks it, a graph of all nine months is displayed as shown in Figure 2.4. This graph combines all of the smaller three-month graphs into a single visualization of the entire school year. This graph is larger than the three-month graphs because all of the months and units must be displayed. However, there is less horizontal space between each month to prevent the graph from becoming too large. Otherwise, it is the same as the smaller graphs. It also has the same three layers and allows users to select or deselect them.

![DPS Earth Science Curricular Flow](image)

Figure 2.4: Full Graph
The smaller three-month graphs make it easier for the user to see precisely when each unit was frequently being accessed. If a user clicks on a specific month, the smaller graphs make it possible to see exactly when in the month the unit started being accessed frequently. In a graph of the entire school year, it would be more difficult to see this because there is less horizontal space for each month. It is also smaller and simpler, so if users only need information about a specific month, they will find it more quickly and easily in the three-month graphs. However, the graph of the entire school year can also be useful. It allows the user to see the curricular flow for the entire school year at a glance. For example, if a teacher wants to see his/her individual flow for the school year, he/she can select the individual layer and quickly see his/her flow instead of having to look at three different graphs.

2.4 Concept Graph

When the user moves the mouse over a line on the graph the concepts viewed by users are displayed under the graph as shown in Figure 2.5. This visualization is a bar graph. The more frequently the concept is accessed, the longer the bar to the right. Concepts that were not viewed are not displayed. There are no numbers on the x-axis because the graph is intended to give the user general idea of how much time was spent in each concept. The concepts are only displayed for selected layers. They are displayed in the same color as the layer they belong to. For example, if the user moves the cursor over a line in the group layer, the concepts are displayed in red. This is meant to prevent confusion if two lines in different layers are close to each other. The concept graph also displays the time period the line covers as well as the unit the concepts belong to.
The concept view is intended to give users an even more detailed view of the curricular flow. It allows users to compare the concepts they are using with the rest of the group or with the recommended flow. Teachers can see if they are spending the correct amount of time on each concept, while administrators can see if the group as a whole is spending the right amount of time on each concept. The concepts in the ideal layer give a clear guide to teachers and are easily compared to individual and group usage. Combined with the layered graph, users can see exactly where they stand compared to others in their group and the ideal flow.

Overall, the visualization starts off by giving users a high level view of the curricular flow of the group and allows them to drill down to more detailed views if they wish. The calendar allows the user to see roughly the group’s flow through the curriculum. They can view a more detailed three-layered graph to see when units are viewed more precisely.
can also compare their individual flow as well as the ideal flow. Users can then drill down even further to a concept view that allows them to see how often each concept in each unit was viewed.

2.5 Research Question 1

The first research question this thesis aims to answer is “What kinds of visualizations can be made from the current CCS data that show the use of the curricular components of the CCS to various stakeholders with different visualization needs?”

Through the creation of the visualization described in this concept, the first research question was addressed. The visualization uses data from the CCS to display the flow of users through the units of the curriculum. By selecting and deselecting the various layers, different type of users can use the visualization to get the information they need.

The visualization is made of two graphs: the unit graph and the concept graph. These two graphs show the usage of different components of the CCS. The unit graph gives users a higher-level view while the concept graph provides a more detailed view. Creating these two different graphs shows that the CCS data can be used to create graphs that show different aspects of CCS usage.
CHAPTER 3

USER TESTING AND EVALUATION

To test the effectiveness of the visualization described in Chapter 2, users were asked to complete three tasks using the visualization.

3.1 Participants

Five people participated in the user testing and evaluation. All five participants had at least some experience using the CCS. Some of the participants had worked on the CCS previously or are currently working to improve it. It was necessary that the participants have some familiarity with the curricula contained in the CCS, so they would understand what was being shown in the visualizations. None of the participants had ever seen the visualizations before. Two of the participants tested the visualization in person, while the other three used Skype and Readytalk.

3.2 Methods to be Employed

The participants were given instructions on how to use the visualization and then asked to do a think aloud exercise while completing the three tasks. In a think aloud exercise, users are asked to say what they are looking at, thinking, feeling, or doing out loud. The tasks ranged from comparing the usage of the individual user and the usage of
the group to determining which concepts were most frequently accessed in a single month. The purpose of these tasks was to exercise some of the major functions of the system. The instructions are included in Appendix A.

3.3 Data Collection and Analysis

While users completed the think aloud exercise, data was collected by taking notes about what they were saying and doing. Their voices were also recorded. After the session was completed, the notes were sorted into several categories to make it easier to report the findings. For example, if the user had several comments about the way months were displayed in the layered unit graph, all of those comments would be sorted into the same category. After sorting the notes, I listened to the recordings, and added any new information that had been missed to the existing categories or created new ones if necessary.

3.4 User 1 Feedback

When selecting the months to display in the graph, the user was expecting only one month to be displayed in the graph. She was confused to see three months displayed at once. However, she also found it useful to be able to see the months around the selected month and suggested that it may be better to give the user the option to choose whether to display one or three months. She also expected the selected month to be displayed in the same position in the graph. Instead, because each graph displays a three-month row in the calendar, the selected month could appear in different positions depending on where it is in the calendar row. She viewed the full graph, but did not use it to complete any of the tasks.
Initially, User 1 was confused about what the line with the square in the middle was supposed to represent. She also found it difficult to see where each line started and began due to the overlap between the different layers. She suggested that it might be better to separate the layers into three rows to make it easier to see the different layers. Because the layers were difficult to distinguish when they were selected, she only used the graph with one layer selected at a time instead of selecting multiple layers. She found it annoying to have to constantly select and deselect layers.

User 1 also found the graph to be too small. The font was difficult for her to make out. The layers were also difficult to distinguish because the graph was too small. If it were bigger, the different lines would be further apart and easier to distinguish from each other. She also suggested that the red and green layers would be difficult to distinguish between for colorblind users. She noticed that there was a lot of white space on the right side of the graph, so there is plenty of room to expand the graph without forcing the user to scroll back and forth.

The user also had trouble figuring out how to select and deselect the different layers. She found the method of clicking the key on the top right of the graph to be unintuitive. She suggested using checkboxes or radio buttons instead to make it more apparent that layers can be selected. Eventually, she did notice the label above the key instructing the user to click the key to select layers, but she only noticed it after she had already figured out how to select layers.

User 1 found the concept graph difficult to understand. Because there was no unit for the bars showing how much each concept was clicked, she didn’t know what the bars were supposed to represent. However, she was still able to complete the task asking which concepts were most frequently accessed in certain months by guessing what the bars were supposed to represent.
The user found it difficult to distinguish where one month on the graph began and another ended. She thought the labels along the x-axis represented the middle of the month rather than the beginning. She found the dates displayed in the concept graph to be helpful in distinguishing the month boundaries. She suggested adding a vertical line at the beginning of each month to mark the boundaries.

User 1 also wanted the graph to have more options for users. She wanted to be able to compare the concepts between different units in addition to being able to compare between different layers. She also wanted an option to hide the deselected layers completely instead of just fading them.

Despite these problems, the user was still able to use the visualization to complete the three tasks in the expected amount of time.

3.5 User 2 Feedback

The user was not immediately able to identify the calendar in the visualization. At first, she thought it was a table. After a few seconds, she was able to see the months at the bottom of the each square, which helped her see that it was a calendar. She also had trouble using the calendar to see which unit was the most frequently accessed in a particular month because she could not tell which unit titles were listed in a larger font. She suggested making the difference in font size more dramatic or using a different color.

Upon first viewing the graph, the user found the graph to be too small. The font was too small to be read easily.

User 2 was able to use the key to select and deselect the layers, and she understood how to use the key. She understood what each layer represented without reading the
instructions. She was able to use the key just by experimenting by clicking on the three
different layers.

User 1 was instructed to select User 1 in the visualization. When selecting between
User 1 and User 2, the user was confused because User 1 was already selected by default,
so she didn’t know what she was supposed to do. It may be better to have both users
deselected when the visualization first loads to prevent confusion.

When clicking on the icon to display a graph, User 2 was expecting only one month
to be displayed at a time and was confused when the graph showed usage over a three-
month period. She clicked on the other surrounding months to see if a different graph
would be displayed. When nothing happened, she clicked months in different rows to see if
the graph would change. She concluded that it didn’t matter which month in the row she
clicked on; she would have gotten the same graph anyway.

She had trouble reading the graph to see if she was ahead or behind the group. She
wanted to be able to compare concepts between lines that were further apart. She also
mixed up the group and individual layers at one point. She also didn’t understand what the
transparent boxes were supposed to represent. When there were two boxes near each other,
she didn’t understand what it meant the user was doing. She thought it may the first box
may represent planning time.

The user felt that displaying investigation numbers would be more useful than
displaying concepts. Investigation data would give a better idea of progress through the
curriculum. In the earth science curriculum, the investigations can be revisited multiple
times through different concepts. The recommended pacing also is based on the
investigation number and not key concept name. Because of this, it’s hard to interpret
progress through the curriculum using the key concept name.
Like User 1, User 2 also thought it would be helpful to have an indication of where each month begins such as tick marks. She was not able to tell that there was a line in April because it was toward the end of the month. She thought the words were at the middle of the month. She had to look at the dates in the concept graphs to know when the lines started and ended. However, she did not realize this until she got to the third task.

User 2 was able to use the graph to complete the three tasks like User 1. She also thought about what the data shown in the visualization might represent, such as the difference between planning ahead and actually teaching the material.

3.6 User 3 Feedback

When the user first clicked the icon to bring up the graph, it did not show up. The user was clicking a little bit above the icon, so it was outside the range needed to bring up the graph. It took him a couple of tries to get the graph displayed.

When the graph came up, the user did not seem to have any trouble using it to complete the first task. However, the user never clicked on the key on the top right of the graph to select the layers. He compared the group layer to the individual layer without ever selecting the individual layer. However, he did not seem to have any difficulty comparing the layers and describing the difference between what the group did and what the individual did.

When completing task 1, user 3 did the task for all three months displayed in the calendar even though it only asked for one month. For example, the first task asks the user to compare their individual usage to the group’s usage in the month of October. The user compared the usage for not only October, but also September and November, which were also displayed in the graph.
At one point, the user mistook one month for another possibly because the positions of the months are not always the same depending on which month is clicked on. For example, October is displayed at the center of the graph, but March is displayed on the left. This may have led to some confusion. However, he realized that he had confused the months after a few seconds and corrected himself.

When clicking on the icon for April after clicking on the icon for March, the user expected the graph to change, and was confused when the graph remained the same. He tried clicking on it several times, but when nothing changed, he used the graph that was already displayed to complete the task.

User 3 never looked at the concept graph for any of the tasks including the third task. He thought “concept” referred to the units displayed along the y-axis. Even when the concept graph was displayed when the mouse passed over one of the lines, he seemed to ignore it. He also never used the key to select the layers for any of the tasks. He was able to compare the individual and ideal layers to the group layer while they were not selected.

There was some confusion over the boundaries between months. For example, the user thought one line was in the third or fourth week of April, but it was actually in the second week. The user suggested that some sort of indication such as tick marks would be helpful. He also suggested adding a way to zoom in on one month to make it easier to see which month the lines were in.

Like with task 1, he did the other two tasks for all three months displayed in the graph instead of just the single month the task asked for. He often started with the month the task required and then went on to the other months rather than doing them in the order they appear in on the graph.

Overall, he said he liked the visualization. He was able to complete the tasks quickly and did not seem to have any trouble comparing the different layers and describing the
differences in the flow between the various layers. However, he did not notice many of the features of the visualization such as selecting layers and displaying the concept graphs.

3.7 User 4 Feedback

When first viewing the visualization, it took a few seconds for User 4 to realize where the user select option was. After finding it, the user was able to select the correct user without any problems.

When the user tried to bring up the graph to complete the first task, he initially thought the entire box was clickable. He first tried clicking on the units displayed in the calendar. However, after a few seconds, he realized that the icon in the corner of each square needed to be clicked to display the graph.

Once the graph was displayed, he found it confusing and didn't know which color was supposed to represent the user. At first he thought the red layer represented the user. It took him some time to notice the key in the top right corner of the graph. Once he noticed it, he experimented by clicking on the various layers, which helped him understand how to use the graph. He realized that the blue layer represented the user. He expected only one month to be displayed in the graph instead of three and said that this made the graph confusing. He also said that it was hard to see the boundaries between the months. He said that if there were only month displayed, it would be easier to tell what month the lines were in.

When going from task 1 to task 2 he was confused when the graph didn't change when he clicked on April after clicking on March. He tried clicking on it several times, but eventually decided to use the currently displayed graph to complete task 2.
Initially, he was not sure how to determine which unit was the most frequently accessed in a month. He did not know the units were displayed on the y-axis. He had to reread the instructions to understand what the titles in the y-axis were supposed to mean. Once he realized that the y-axis was supposed to represent the units, he was able to use the graph to determine which unit was the most frequently accessed in April. To determine the most frequently accessed unit in November, he used the calendar instead of using the graph.

When completing task 3, user 4 tried to hover over unselected units to display the concept graph and was confused when the graph didn’t display. After a few seconds he tried selecting the layer and then hovering over it to display the concept graph. He completed the task for all three months instead of just the single month the task asked for. He said he found it difficult to determine which concept was the most frequently accessed across all units from the information that was displayed in the graph.

User 4 initially did not understand what the bars in the concept graph were supposed to represent. Eventually, he realized that the length of the bar corresponded to the usage of the concept. He suggested that the concept graph needs more explanation such as an axis that explains what the length of the bar means. He also found it difficult to compare the usage of concepts across units.

Throughout the session, he was hovering the mouse slightly above the squares on the lines of the graph, so the concept graph did not display. This was also a problem when selecting layers. Because of this, it often took a few tries to select or deselect layers and a few seconds to display the concept graph.

He was able to complete all three of the tasks, but overall, he found the graph somewhat difficult to understand. He had to refer back to the instructions several times to understand how to read the graphs.
3.8 User 5 Feedback

When first viewing the calendar, the user did not realize it was a calendar because she did not notice the months. After she noticed the months at the bottom of the square she realized it was a calendar.

To display the graph, the user first tried clicking on the month displayed in the calendar square, and when nothing happened, she then tried clicking on the unit names. When the graph still didn’t display, she tried clicking on the icon in the corner, which finally brought up the graph.

When viewing the graph, user 5 didn’t understand how concept usage is shown or what the concept graph was supposed to be showing. When she first viewed the concept graph she didn’t know what the red color was meant to represent. She wondered if the concept graph referred to her usage. She also was unsure how to compare her own usage to the group’s usage. She was able to use the key in the top right corner to select and deselect the layers. Once she did this she was able to display the concept graphs for both the group and the individual user, and she understood how to compare the concept graphs. At first she thought the graph didn’t change if she hovered over a different line, but after hovering over two or three different lines, she realized that the graph does change. Eventually after familiarizing herself with the graph a bit more she was able to compare the group’s usage of the units to her own.

When reading the instructions, she thought that the information about the different text sizes referred to the unit graph instead of the calendar.

User 5 completed task 1 for all three months displayed in the graph instead of just the single month the task asked for. At first she only did the task for October, but then she thought she needed to compare usage in September and November as well. When doing the
task for March, she also did it for both April and May. She was also confused about the boundaries between the months. Unlike other users, however, she did not mention expecting one month to be displayed instead of three.

When completing task 2, she did not understand how to find out which unit was the most frequently accessed and said that the lines don’t show popularity. She didn’t understand what was meant by “popularity”, and she wondered whether she should look at the group’s usage or her own usage to determine which unit was the most frequently accessed.

For task 3, she was unsure how to compare her own concept usage to the group’s or the ideal because the graphs for different groups often displayed different concepts.

Throughout, the session she had a bit of trouble selecting the layers and displaying the concept graphs because the range the mouse cursor had to be within was too small. It often took several clicks to select a layer. She said that the graph was “really touchy” as to when it would display the concept graphs.

Overall, user 5 had difficulty completing the three tasks. She did not understand how to compare the different layers to each other and how to determine which units were the most frequently accessed. Eventually she decided to concentrate on the group usage to compare usage of the units. She would also give the most frequently accessed units in her own usage, but she would state that this was probably not the most frequently accessed unit overall. She referred back to the instructions many time while doing the tasks and said that it was difficult to read the instructions and do the tasks at the same time.
While all of the users were eventually able to use the visualization to complete the three tasks, there were several problems that commonly occurred. The most common problem users seemed to have was the lack of indication of where the boundaries between the months. This was a problem for all five of the users who tested the visualization. Three out of the five users suggested adding some sort of indication such as lines or tick marks to make it clear when each month ended and began.

Four out of five users also expressed confusion when they clicked on one month and got a graph, which displayed three months. Two users completed the tasks for all three months displayed instead of just the single month the task required. One user suggested that the month boundaries would be clearer if only one month was displayed.

There was also some confusion about what the length of the bars in the concept graph was meant to represent. Three users expressed confusion over how to read the concept graph. They all eventually guessed that the longer bars corresponded to more frequently accessed units, but they said they would prefer some explanation of what the bar lengths represent.

Three users found the range the mouse needed to be in the display the unit graph, concept graph, or select the layers to be too small and it often took several tries to get the information displayed. One user said the graph was “really touchy.”

When first viewing the graphs, two of the users thought the red layer might represent the individual instead of the group. Both of them eventually noticed the key, which helped them realize that the red layer represented the group and the blue layer represented the individual.
Two users found the graph to be too small and had difficulty reading it. They felt it would be easier to distinguish the line from each other and read the labels if the graph were larger. These two sessions were done in person, so the problem may have been the result of the higher resolution of the computer used for the in person sessions.

Two of the users had to refer to the instructions several times while completing the tasks and one user said that this made the tasks more difficult to complete because it was too much of a cognitive load.

There were several features of the visualization that were not used much by the users. Only one of the users viewed the full graph and she did not use it to complete any of the tasks. One user used the units displayed in the calendar to complete the second task and he only used it to determine which unit was most frequently accessed in the second month asked for by the task. All of the other users used the unit graphs to complete the second task. One user did not select or deselect any of the layers or look at any of the concept graphs.

Despite the confusion, all of the users were eventually able to compare the usage of the units between the different layers. All but one of the users were also able to compare the concept usage within a layer, though there was some confusion about how to compare concept usage between different layers.

3.10 Recommended Changes

There are several changes that could be made to alleviate some of the problems users had. Many users were confused by the lack of month boundaries. A simple way to solve this problem would be to add a vertical line indicating the beginning of each month. Displaying one month at a time instead of three would be another solution.
Several users also had trouble understanding what the length of the bars in the concept graphs was meant to represent. A label could be added at the bottom of the graph such as “number of clicks” to show what the bars mean.

Many users had trouble realizing that the key could also be used to select or deselect layers. Checkboxes could be added to make it clearer to users that the key can be clicked on to change the graph.

Some users often had trouble displaying the concept graphs or selecting layers. The range the mouse needs to be in could be made larger.
CHAPTER 4

ARCHITECTURE, TOOLS, AND IMPLEMENTATION

Processing, a multi-platform open source graphical programming language and environment [15], was used for the visualizations created for this thesis. Projects created in Processing can run as either native desktop platform applications or online through a web browser, and can be interactive to allow users to interact with visualizations with the mouse. Processing has a large and vigorous community of users and practitioners ranging from prototype proof-of-concept development projects to full blown production-deployed applications. This community is supported by many resources, tutorials, and demos. The Processing forum is a good source of information, demos and tutorials for users looking for inspiration and help using Processing. Processing is also well documented and there are even several books [13, 14] detailing its use.

Processing can detect the position of the user’s mouse, and the $x$ and $y$ position of the mouse can be obtained by using the mouseX and mouseY variables. By using these two variables, it is possible to display the concept graph when the mouse is hovering over a line on the graph. The mouseClicked function can be used in combination with the mouseX and mouseY variables to alter the graph if a certain area is clicked. When the mouse is clicked the $x$ and $y$ positions of the cursor are checked. For example, in the graphs created for this thesis, if the mouse is over one of the boxes in the top right corner when it is clicked, the corresponding layer is selected or deselected.
4.1 Displaying Projects on the Web

In the past, to display Processing projects on the web, Processing would allow the user to export projects as Java Applets. These would require an external Java plugin to run. In more recent versions of Processing, JavaScript has replaced the need for Java, requiring the use of a single JavaScript library Processing.js. Processing.js is a sister project that allows users to display projects created in Processing on the web by using the HTML5 canvas element. It uses a combination of the code written in Processing in addition to an automatically generated JavaScript file to display the project online. When the user exports the project, two files are generated that need to be added to the user’s website. One of these is a .pde file that contains the Processing code. The other is a JavaScript file that can be used with any .pde file to generate the user’s visualization. This allows projects to be displayed on a web page without the need for external plugins such as Java while retaining all of its original functionality.

While Processing has a library that allows users to import data from a database, this library does not work in Processing.js. This is because the library is written in Java by a third party. While Processing.js is able to convert the Processing code to JavaScript, it is not able to change external libraries. This prevents any external libraries from working in Processing.js including Java libraries. Unfortunately, this makes it impossible to import data from a database unless it is on a server. This was a limitation for creating the visualizations for this thesis because the database containing the data needed for the visualization was only accessible locally.
However, Processing allows the use of both arrays and ArrayLists. For the visualizations created for this thesis, an ArrayList was used instead to insert the data needed to generate the graphs. A single ArrayList can contain many different types of variables. For example, an ArrayList can contain both integers and strings. When an element in the list is accessed, it needs to be cast to the correct type to be used. This allows users to use a single list instead of having to use many different lists to contain different types of variables.

4.2 Graphical Programming in Processing

Processing has a draw class that runs 60 times per second. This is the class in which all of the elements to be displayed must be created after the initial setup class runs. For the concept graph, it was necessary for the background to be reset after the user stopped hovering over the line. Otherwise, the concept graph would continue to be displayed even after the user stopped hovering over the line. If other lines were hovered over, they would be overlaid over the earlier graph. If the background is reset every frame, this problem is eliminated. Specifying a background color in the draw class instead of the setup class can easily reset the background.

Processing is an interesting tool for visualization because it is very versatile. It can be used to make not only graphs, but also images and animations. Projects can be in 2D or 3D. Users can create various shapes such as squares, circles, and triangles. They can also display text. The ability to display lines and text makes it very easy to create graphs in Processing. Unlike many other visualization tools, there aren’t specific types of graphs Processing allows the user to create. Users can use the available classes and functions to
create any type of graph that they need. This made it very simple to create both the layered unit graph and the concept graph and display them both together in the same visualization. It also allows users to create unique graphs that would be impossible using a library that only allows certain types of graphs.

4.3 Other non-Processing Libraries for Data Visualization

Though Processing was used for this project, there are many other libraries for creating visualizations available that were considered, but not used. One such library is the JavaScript InfoVis Toolkit [16]. It is a JavaScript library that allows the user to create many different charts such as trees, pie charts, and bar charts. It also allows for animations to make the charts more interesting to use. While the demos on the homepage seem to show many different types of charts, the API documentation includes more types such as area charts, pie charts, tree maps, and radial graphs. Users can manipulate the graphs in many different ways such as adding and removing data or changing the canvas or labels.

Another library for creating visualizations is Highcharts [17]. Highcharts is written in pure JavaScript, so users do not need any external plugins such as Java or Flash. It allows users to create many different types of charts such as line, spline, column, bar, and polar charts. Many of these different types of charts can be combined into a single chart. Data can be added or removed and the axes can be changed after the chart has been created. Users of charts created using Highcharts can move the cursor over the graph and the tooltip will display additional information. Charts also allow zooming. The homepage also has many demos of all of the different chart types.

Other libraries for creating visualizations include R [18] and Visually [19]. Like Processing, R has very strong community and provides users with a wide variety of
statistical and graphical techniques. It is similar to the S language developed at Bell Laboratories. Visually allows users to create data visualizations and infographics and makes it easier for people to make, distribute, and share infographics.

While Processing’s versatility made it a useful tool for creating the visualizations in this thesis, there are also other possible solutions. Highcharts allows for many different chart types and the tooltip may have been useful for creating the concept graph. However, like Processing.js, it would not have been able to access a local database because it is written in JavaScript. It is also a relatively new library, so it does not have the large community that Processing has, which would make it more difficult for new users to get help.

4.4 Tools used for calendar

The calendar visualization was created using HTML, CSS, and JavaScript. The calendar was easily implemented using an HTML table. Each month was a different cell in the table. When the user clicks on the icons in the bottom right corner of each cell, a JavaScript function is called to display the corresponding graph and hide all of the other graphs. Because the Processing graph runs automatically when the web page is loaded, the CSS visibility property was used to hide and display the graphs. When a graph was displayed, its visibility property was set to “visible” while the visibility properties of the other graphs were set to “hidden”.
4.5 CCS Data

The visualizations created for this thesis display information from the CCS to allow users to see their own usage to make comparisons. Data from the CCS must be accessed and displayed in a meaningful way. In order to do this, it was important to understand what data the CCS can provide and what it means.

4.6 CCS Curriculum

The curriculum used for this thesis is the “Investigating Earth Systems” curriculum. The Investigating Earth Systems curriculum contains 5 units: Investigating Rocks and Landforms, Investigating our Dynamic Planet, Earth in Space, Water as a Resource, and Climate and Weather as shown in Figure 4.1. Each unit contains one or more chapters. In the earth science curriculum, unlike some of the other curricula, there is only one chapter in each unit. Because of this, instead of displaying which chapters were most frequently used, the visualization displays which concepts were most commonly used instead.
Each chapter contains several key concepts. The key concepts contain resources about a specific concept in the chapter. For example, the “Rocks and Landforms” chapter contains key concepts such as Earth’s Crust, Erosional Processes, and Delta & Floodplains among others as shown in Figure 4.2. Each concept also contains one or more investigations, which are activities teachers do with the students in the classroom.
### Key Concepts

<table>
<thead>
<tr>
<th>a. Earth's Crust</th>
<th>e. Erosional Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Earth’s crust is made of rocks which can be igneous, sedimentary or metamorphic.</td>
<td>Weathering and other erosional processes involve the geosphere, hydrosphere, atmosphere and biosphere. Erosion can be the result of running water, wind, glaciers and gravity. Some landforms are shaped by erosion.</td>
</tr>
<tr>
<td>- Introduction to Rocks and Landforms</td>
<td>- Investigation 4: Rock Abrasion</td>
</tr>
<tr>
<td>- Investigation 1: Different Types of Rock+</td>
<td>- Investigation 5: Erosional Landforms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b. Rocks by Region</th>
<th>f. Delta &amp; Floodplains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different types of rocks occur in different regions.</td>
<td>Delta and floodplains are formed by sediment deposition.</td>
</tr>
<tr>
<td>- Investigation 2: Rocks and Landforms in Your Region</td>
<td>- Investigation 6: Delta and Floodplains*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c. Rock Cycle</th>
<th>g. Glacial Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocks form and break down by processes collectively known as the &quot;rock cycle&quot;.</td>
<td>Glaciers are masses of ice that flow slowly under their own weight and can erode and deposit particles to form landforms.</td>
</tr>
<tr>
<td>- Investigation 1: Different Types of Rock+</td>
<td>- Investigation 7: Glaciers, Erosion and Deposition</td>
</tr>
<tr>
<td>- Investigation 3: Rocks and Weathering+</td>
<td>- Investigation 8: Rocks, Landforms and Human Activity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>d. Weathering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocks break down through a process called weathering, which is part of the rock cycle. There are three types of weathering: physical, chemical, and biological. Different types of rock might be affected differently by weathering processes.</td>
</tr>
<tr>
<td>- Investigation 3: Rocks and Weathering+</td>
</tr>
</tbody>
</table>

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**Figure 4.2: Rocks and Landforms Key Concepts**

### 4.7 Clickstream Data

The CCS stores clickstream data about what resources the teachers accessed as well as when they accessed them. Each click has a time associated with it, so it is possible to track a user’s usage over time. The database contains the unit, chapter and concept that were accessed. If the user logged into the CCS, but did not access any unit, the value of the unit in the database is NULL. This is also true of the concept if the user accesses a chapter, but not any of the concepts. The entries for which the unit and chapter were NULL were
removed to make it easier to see which units and concepts were the most frequently accessed. It also stores the user's individual ID, so data about an individual user's usage can be accessed. The database also stores the user's district, so an entire district's usage can be tracked. This data can be used to compare the usage of an individual to the entire district.

4.8 Pacing Guide

The recommended pacing guide shows how much time the users are expected to spend on each unit as well as on each investigation. It does not contain much information about the order in which the units should be taught. It recommends teaching the “Modeling” concept in the “Our Dynamic Planet” unit first, but there is no information about when any of the other concepts should be taught. For the visualizations created for this thesis, the recommended pacing is shown as teaching the units in the order they appear in the pacing guide. Therefore, after the “Modeling” concept, the first unit taught is Investigating Rocks and Landforms, the second is Investigating our Dynamic Planet, the third is Earth in Space, the fourth is Water as a Resource, and the fifth is Climate and Weather. This data can be combined with data obtained from the database to compare usage to the recommended pacing. Both an individual’s usage and the district’s usage can be compared.

4.9 Creating visualizations

Because Processing is so versatile, creating the two different types of graphs was straightforward. To create the graph of the units, a unit and a start and end point was
obtained from the ArrayList for each line on the graph. Using this information, the line was drawn in the correct position. To create the concept graph, the concept names and amount of time spent in each concept was obtained from an ArrayList, and a bar graph was created from this information. The height of the bar corresponds to the amount of time spent on the concept. The longer the bar, the more time was spent on that particular concept.

To detect whether or not the mouse was hovering over a particular line, the `mouseX` and `mouseY` variables were used. If the x value was between the start and end points and the y value was within five pixels above or below the line, the concept graph corresponding to that line would be displayed below the line. A similar method was used to select or deselect layers. Processing has a `mouseClicked` function that runs automatically when the mouse is clicked. A layer would be selected if the mouse happened to be over the correct box in the upper right corner when the mouse was clicked. If the mouse is not in that position, nothing happens when the `mouseClicked` function runs.

Using Processing, I was able to achieve all of the features described in Chapter 2. In addition to being able to create both the unit graph and the concept graph, I was also able to create the three different layers without difficulty. A Boolean was used to represent each layer. When a layer was selected, the Boolean was set to true and when it was deselected, it was set to false. When the Boolean was true, the lines in that layer were drawn at the maximum opacity, and when it was false, they were drawn at a lower opacity. This method made it possible to make the selected layer stand out from the deselected layers to allow comparison between the different layers. All three layers could be displayed and understood in a single graph. An “X” was drawn next to the selected layer's label in the upper right corner of the graph. The X was only drawn if the layer’s Boolean was set to true.
While it was possible to implement all of the features described in Chapter 2, it was not possible to use actual data from the CCS in the graphs. Unfortunately, because it is not possible to access the local database using Processing.js, the solution described in Chapter 2 could not be fully implemented. To test the current solution, it was necessary to use data stored in an array instead of accessing the data from the CCS directly. Because of this, the current solution could not be used in the CCS to allow teachers to show their progress and compare it to that of others.

4.10 Limitations

In the current prototype, there is no error handling. Therefore, if the data in an ArrayList is not in the correct format, the graph will not display correctly. This could be improved by adding error handling where data is being obtained from the ArrayList. It might also be useful to add checks to see if the data is in the correct format before proceeding. Currently, there is no check, so if there is a problem with the data, the program will just stop running and the graph will not display anything. It might also be useful to display an error message if this occurs, informing the user that there is something wrong with the data.

Another problem is that sometimes the lines will overlap each other. In the current prototype, the group layer is drawn first, followed by the ideal layer, and then the individual layer. Because of this, the lines in the ideal layer will overlap the lines in the group layer, and the lines in the individual layer will overlap lines in both of the other two layers. This overlap is not much of a problem when the layers are deselected because both lines will still be visible, but if the layers are selected, one line will obscure the other. While the squares drawn on each line help it remain visible to the user, it is still impossible to see
the total length of the line. It may be possible to improve this by redrawing the line if the user hovers over it. This way, if the user is interested in that particular line, he/she can see the total length of the line. However, if one line is completely behind another line without any part of it outside the range of the line in front of it, it is not possible for the user to hover over the line in the back without hovering over the line in the front. One solution to this problem might be to redraw the line if the user hovers over the square in the middle of the line. Unless the squares on both the line in the back and the line in the front are in the same position, this would help solve this problem. Unfortunately, if the two squares are in the same position, the user would not be able to see the line in the back at all, so it would not be possible for him/her to hover over it.

4.11 Advantages and disadvantages of implementation decisions

One of the first choices I made when creating these visualizations was to use red, green, and blue for each layer. Red was used for the group layer, green was used for the ideal layer, and blue was used for the individual layer. The reason I chose these colors was because they are easy to distinguish from each other. This made it possible to display the three different colors in a single graph. These three colors also stood out against the white background of the graph so the user could easily see the lines. While the shades of red and blue I chose were dark enough to stand out from the background, the shade of green I had chosen initially wasn’t as easy to make out. I decided to use a darker shade of green that would be easier to see. These three colors are also easy to distinguish from the black axes and labels of the graph making it easy for the user to distinguish the different parts of the graph.
I also decided to use opacity to display whether or not a particular layer was selected. The advantage of this method was that it allowed three different layers to be displayed in a single graph. Another way to communicate to the user that there are three different layers would have been a 3D graph. A 3D graph may have been better for representing the concept of layers. However, the current approach makes it easier to compare the three layers to each other, which is an important purpose of this visualization.

Another choice I made was to include a key at the top right corner of the graph that displayed which color represented which layer. This worked as a quick way to inform the user about the layers and how to read the graph. The key can also be used to select a particular layer. Because it is already working as a key, it can be used for both functions without the need to add another way to select layers. This helps save space for the actual graph. However, it might be difficult for users to realize that the key can also be used to select layers. They might think that the key is just a key and has no other purpose. The key is also a bit small, so it might be difficult to click on the correct layer. While it may have been better to have a larger key, it would also make the graph larger, which would make it more difficult to display easily. The current graph fits easily on a computer screen with the calendar to the left. If the graph were larger, it would be more difficult to display both the calendar and the graph together on the screen. The user would then have to scroll around to use the visualization, which would be more inconvenient.

I also had to decide how to display to the user that a particular layer was selected. Currently, an “X” is displayed next to the name of the selected layer. The reason this was chosen is because it was very easy to implement and it is a simple way of communicating to the user that the layer is selected. However, because it is so small is might be difficult to notice easily. Another method, such as drawing a rectangle around the name of the selected layer may be more noticeable. However, because the names of each layer are so close
together, it might be difficult to draw the rectangle around one name without overlapping any other rectangles. It is also not as easy to implement as simply drawing an X.

Another choice I made was to display the concept graph underneath the unit graph instead of overlaying it. If the concept graph is underneath, the entire unit graph still remains visible to the user. If the user wants to be able to view both the unit graph and the concept graph at the same time, this method allows that. However, this method also makes the graph larger than it would be otherwise. The extra space could be used for the larger key mentioned earlier, for example. However, in the end I felt that being able to view the entire graph would be more useful to the user.

4.12 Research questions

Through creating these visualizations in Processing, I was able to answer the first of the research questions discussed in Chapter 1. The versatility of Processing allows me to create many different types of visualizations including the graphs described in Chapter 2. However, because Processing.js is not able access local databases, it was not possible for me to create a visualization using the complete live CCS data.
CHAPTER 5

CONCLUSION

Through creating and testing the visualization described in chapter 2, I was able to address the three research questions introduced in chapter 1.

5.1 Research Question 1

The first research question this thesis aimed to answer was “What kinds of visualizations can be made from the current CCS data that show the use of the curricular components of the CCS to various stakeholders with different visualization needs?” In order to answer this question, data from the CCS was used to create a graph that displayed the progress of a single user, a group of users, and the ideal curricular flow. Users can see which units were accessed when and what concepts within each unit were most frequently used during that time. Three different layers were used to display this information. The red layer represents the group, the green layer represents the ideal flow, and the blue layer represents an individual user. Each layer can be selected and deselected to allow the user to adjust the graph depending on his/her needs.

Data from the CCS database was used to create the visualizations, but the data used for the visualizations in this research only displays data for a single district, which showed data only for the users who were affiliated with that district. Individual user data was used to access data for two individual users for the individual layer of the graph. The database
also contained the unit and concept as well as the date and time when the user accessed them. The unit data was used to create the lines in the unit graph while the concept data was used to create the concept graphs.

The visualizations can be used in various ways depending on what information the user needs. For example, a teacher can compare his/her own usage to the ideal to see if he/she is ahead or falling behind, or an administrator can compare the group’s usage to the ideal to see if an entire school or district is keeping up with the recommended flow. This allows users with different needs to potentially use different aspects of the same visualization.

Using Processing, it was possible to create both the unit graph and the concept graph. The calendar was created using HTML and CSS, and JavaScript was used to display and hide the graphs. The versatility of Processing allowed the creation of many different types of graphs, making it simple to create the types of graphs needed to show the CCS data. Processing is able to detect the position of the user’s mouse, making it possible to display the concept graphs when the user hovers over a line in the unit graph.

Through creating the various graphs to display information from the CCS, I learned about the difficulty of displaying such a large amount of information in a small amount of space. The way this problem was handled in the visualizations was by starting off with a high level view that displayed a smaller amount of information. The user could choose to view additional information by displaying the unit graphs and even more information by hovering over the lines. The three layers of the unit graph also helped in displaying a large amount of information. I was able to display information about all three layers in a single graph without overwhelming the user.
5.2 Research Question 2

The second research question was “How will teachers and high-level administrators react to the proposed mockups that develop as a result of the first question?” To answer this question, tests were conducted with users who were familiar with the CCS. They used the visualization to complete three tasks. The tasks were meant to reflect the ways in which actual users might use the visualization. The purpose of this testing was to see if the users were able to complete the tasks and what difficulties they might have in using the system. All of the users were able to use the visualization to complete the three tasks; however, there were several problems that almost all of the users had. The most common problem users had was distinguishing where one month ended and another began. Many of them suggested adding lines or tick marks to help indicate the boundaries. Many users were also confused when they clicked on the icon for a certain month and a graph showing three months was displayed. Several users also completed the tasks for three months instead of just a single month, possibly because of this confusion. It may be better to display only a single month and give the user an option to view the three-month calendars. This would also make it clearer where the month boundaries are.

Users who tested the visualization never accessed the full graph to complete the tasks. This may have been because the tasks always asked users to look at a single month, which would have been easier using the three-month graphs rather than the full graph. It would be useful to create tasks that would be more likely to require use of the full graph and conduct more user testing to see if users would use the full graph if the situation called for it.

One user said that displaying the investigations instead of the concepts would be more useful in showing curricular flow. In the Earth Science curriculum used for the
visualizations, the recommended pacing is based on investigation number and not on key concepts, and investigations are often revisited in later concepts. However, in other curricula, the pacing is based on key concepts. It might be necessary to display either investigation numbers or key concepts depending on the curriculum.

From the user testing, I learned the importance of making it clear how the graphs should be read. Even though many things were labeled, there was still confusion among users about how to correctly read the graph. In addition to the problems with distinguishing month boundaries, some users also had trouble understanding which layer represented the user. However, all five of the users were able to use either the instructions or the key to eventually figure this out.

On the other hand, users were also quick to notice certain features that I had thought they might miss. Most of the users had no trouble finding the radio buttons that allowed them to choose between User 1 and User 2. Many users found them immediately without any trouble even though they were at the bottom of the screen. Most of the users were also able to guess what the lengths of the bars in the concept graph were meant to represent despite the fact that many of them commented on the lack of labeling.

5.3 Research Question 3

The third research question was “What was the impact of the proposed implementation and how might they be improved for future integration and study within the CCS?” During the user testing, all of the users were able to use the visualization to compare the various layers to each other and complete all three of the tasks, even though some users had more difficulty than others.
One problem that was discovered during the implementation of the visualization was that a local database could not be accessed in Processing.js. This is because the library that allows Processing to access a local database was written in Java and cannot be converted to JavaScript by Processing.js. As a result, it was necessary to use an ArrayList to insert the data into the visualization. However, this solution makes it more difficult to integrate the visualization into the CCS. It may be necessary to find a different solution that allows access to a database.

While the visualization does allow users to make comparisons between the various layers, there are many improvements that could be made in the future in addition to the way months are displayed. One issue was that the size of the graph displayed seemed to depend on the resolution of the user’s screen. This meant that the graph looked too small on higher resolution screens and made it difficult to distinguish between the individual lines and read the text. In the future, the visualization should be tested on multiple screens to make sure it is not too big or too small on any screen.

Users also found it difficult to click on the layers in the key to select or deselect the layers. It might be useful to expand the range in which the user has to click to select a layer or hover to display the concept graph. It was also difficult for users to realize that the key could be clicked on to select a layer despite the instructions and the label above the key. It might be better to use checkboxes instead, so that users can tell the layers can be selected just by looking at the key without having to read anything.

More labeling is also needed to explain how the graph should be read. Lines or tick marks indicate where each month ends and begins would make it easier for users to see what period of time each line is supposed to represent. This would allow users to understand and compare their curricular flow more easily. The bars in the concept graph also need labeling to explain what the length of the bar means. While most users were able
to guess that the longer bars corresponded to more frequently accessed units, they had difficulty comparing the concepts between different units.

Through implementing the visualization, I learned about the important differences between Processing and Processing.js. No Java classes can be used in Processing.js, so the Date class could not be used. It was also not possible to use Processing libraries such as the library that allows data from a local database to be accessed. It was necessary to find workarounds to create the visualizations.

5.4 Summary of Research Results

Though there are many aspects to this research that require further investigation and reflection, four major takeaways of this research are enumerated below:

1. Layers can be used to display a large amount of information in a small amount of space.
2. The ability to select and deselect the layers can allow different types of users to get the information they need from the same visualization.
3. Users are able to use the layers to make comparisons between the curricular flow of a group and the flow of an individual user.
4. While Processing.js can be used to implement this type of visualization, it cannot connect to a local database.

Clearly, more changes could be suggested, and with an even larger battery of user testing new feedback could change the kinds of information gains that might be seen, but the system as it stands now represents a first step forward in developing the kinds of capabilities that could be useful to teachers using systems that are designed to improve their planning and pedagogy. As systems such as the CCS take their place as the norm in
the educational landscape of tools designed for teachers, visualizations such as those presented here will likely become commonplace, opening new opportunities to understand how these systems impact their users and the kinds of data that may be presented to end users to increase and enhance the value of the systems they use. This research represents but the start of a trend toward data analytics in educational contexts designed to improve end user access, and quite possibly effectiveness as data becomes that standard by which decisions at all levels of education are being made.


APPENDIX A

INSTRUCTIONS TO SUBJECTS IN USER STUDY
User Review of CCS Visualization
Kirun Agarwal, Keith Maull

Purpose
I have created a visualization that is meant to help users visualize activity in the CCS. The purpose of the task you will be performing today is for me to see what information you can learn from using the visualization and how it can be improved in the future.

Details
The visualization you will be looking at shows the curricular flow through DPS's earth science curriculum. By this we mean the units, chapters and curricular elements that have been accessed during the displayed time periods. When you first view the visualization, you will see a calendar of the school year. Each square contains the most popular units during that month. More popular units are displayed in larger text. At the lower right corner of each square there is a small icon you can click on to display a graph.

Once this icon is clicked, the graph shows when each unit was popular among users. A line is used to represent the period of time during which the unit was popular. You can hover your mouse over the lines to view a graph of the most popular Concepts during that time period. The popularity of the Concepts is shown using a bar graph.

You can click on the key on the top right of the graph select different layers. The group layer is red, the ideal layer is green, and the individual layer is blue. The group layer shows the curricular flow of the entire DPS school district. The ideal layer shows that pacing recommended by the school district for this curriculum. Finally, the individual layer shows the flow of a single user of the CCS. When a layer is selected, it becomes opaque. Deselected layers are partially transparent.

What You Are Being Asked To Do
You will be performing a think aloud task while I record and take notes of what you are saying and doing. There will be several tasks you must complete using the visualization. I will observe how easy/difficult it is to complete the tasks. Feel free to suggest any improvements you can think of.

Task 1: Imagine you are “User 1”. Select “User 1” and examine the flow and find out how your usage compares to others in October? Now examine March?
Compare your own usage to that of others. What are the similarities and differences between your usage and the group’s usage?

Task 2: Determine which units were popular when?
Determine which units are the most popular in the month of April? How did your usage compare to the popularity in that month? How about November? How did your usage compare among all users during the same months?

Task 3: Find out what concept was most popular in a month?
Determine which concept is the most popular in the month of January for all units. Compare the most popular concepts among all users to the ideal flow. Now do the same for the month of April.
User Review of CCS Visualization
Kirun Agarwal, Keith Maull

Purpose
I have created a visualization that is meant to help users visualize activity in the CCS. The purpose of the task you will be performing today is for me to see what information you can learn from using the visualization and how it can be improved in the future.

Details
The visualization you will be looking at shows the curricular flow through DPS's earth science curriculum. By this we mean the units, chapters and curricular elements that have been accessed during the displayed time periods. When you first view the visualization, you will see a calendar of the school year. Each square contains the most popular units during that month. More popular units are displayed in larger text. At the lower right corner of each square there is a small icon you can click on to display a graph.

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You can click on the key on the top right of the graph select different layers. The group layer is red, the ideal layer is green, and the individual layer is blue. The group layer shows the curricular flow of the entire DPS school district. The ideal layer shows that pacing recommended by the school district for this curriculum. Finally, the individual layer shows the flow of a single user of the CCS. When a layer is selected, it becomes opaque. Deselected layers are partially transparent.

What You Are Being Asked To Do
You will be performing a think aloud task while I record and take notes of what you are saying and doing. There will be several tasks you must complete using the visualization. I will observe how easy/difficult it is to complete the tasks. Feel free to suggest any improvements you can think of.

Task 1: Imagine you are “User 2”. Select “User 2” and examine the flow and find out how your usage compares to others in October? Now examine March?
Compare your own usage to that of others. What are the similarities and differences between your usage and the group’s usage?

Task 2: Determine which units were popular when?
Determine which units are the most popular in the month of April? How did your usage compare to the popularity in that month? How about November? How did your usage compare among all users during the same months?

Task 3: Find out what concept was most popular in a month?
Determine which concept is the most popular in the month of January for all units. Compare the most popular concepts among all users to the ideal flow. Now do the same for the month of April.