Interactive Web-based Visualization Tool to Support Inquiry-based Science Learning
Abstract
This thesis introduces the idea of an interactive web-based visualization tool to support inquiry-based science learning. The problem that occurs when the teachers and students are discussing the collected data is that they are lacking a tool to display such large quantities of data. It is often hard to fully understand such data. This education tool makes use of different visualization approaches in order to support students while getting insights from their collected data. In this thesis I proposed and implemented an interactive web-based visualization tool that was used at a prototype level during the educational activities. The requirements and user needs led the development of this prototype. Requirement elicitations have been done as a part of the research project conducted by CeLeKT.

For the development of this tool, it was necessary for the input of the teachers and students in order to get an understanding of the requirements. The initial inquiry of the teachers and students show the necessity and usefulness of an interactive web-based visualization tool to support learning practices.

Keywords
Visualization, Web-based Tool, Inquiry Learning, Interactive, Science Learning, Sensor Data
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1 Introduction

Visualization is more than just giving basic text life. It emphasizes communication, education, collaborative work and problem solving (Manore 2007, p. 24). New possibilities for education are created with the use of newly adapted web-based technology, especially through new visualization techniques (National Science Foundation 1999, p. 2-3). The way that schools are able to use data-related tasks has changed profoundly; some examples are the use of data collection, new storage opportunities, faster transmissions and clearer displays (Johnson et al. 2010, p. 29). The way that we now present the most complex data in the simplest structure, so that in a way anyone, of any age, can look at a slice in a pie chart and understand its proportion (Wilkinson & Graham 2005, p. 23). Visualization is dominated by three areas such as information, scientific and software visualization (Holmberg 2004, p. 1). In this thesis I will adapt the definition of information visualization, which is defined as the following:

“the use of computer-supported, interactive and visual representations of abstract data to amplify cognition.”

Card, Mackinlay and Shneiderman (1999, p. 7)

This definition emphasizes the need for interactive computer software that would help in the presentation of different datasets. These datasets then could be used to support learning. Implementing these new technologies into varied classrooms and getting students to use them for various educational methods such as experimentation, research and learning is a difficult process. Moving away from the old fact-based learning to newer technologically based methods is a problem that current teachers are facing (Johnson et al. 2010, p. 4). This way of learning is formally known as inquiry, which is defined as:

“Inquiry is an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding.”

National Science Foundation (1999, p. 2).

Environmental science learning has been present in schools since our world started to industrialize. Also the way that data values have been collected has remained consistent. Previously the education that students received about the environment was just facts. The students learned in books about the problems of the earth but did not take part in solving them. This is how the past and the present times are different. Today it is necessary for students to take part in their learning. With the help of technology this has become a new possibility. Students are now able to understand what they are doing through graphic visualizations (UNESCO 2010).

Through these new technologies and the use of mobile devices they now make it possible to save various types of data in new ways. Vogel et al. (2010) presents how the design and implementation of mobile and web applications could be used in environmental science. Furthermore, the task at hand that the students were given was to go out into the environment. They were required to collect certain values, such as pH and temperature. With the use of a mobile device, they were able to immediately store the data as well as their location. This thesis
will make use of this kind of data. The purpose will be to explore how students respond differently at the time of discussion with the use of modern visualization techniques. This is in contrast to how students previously had to look at the information that they gathered.

To be able to discuss the mobile data we need to move it over to a user-friendly environment. Hans Rosling states that the data exists, but it is not being used properly in a beneficial way. He says that the data is out there but is not obtainable by the average person without cost. Often data is displayed in a tedious way that is not interesting to people (Rosling 2006).

This thesis will explore how students can use data and visualize it so that they will feel more motivated. This will also help them to discuss what the data actually means. To do so a visualization tool will be made to replace the data with different types of animated and static visualizations.

In order to satisfy the requirements that the students and the teachers have, this tool must use the combination of different types of mashups and API's (Application Programming Interface). It will present mobile sensors, such as GPS-positions with the use of online geo-maps, and interactive graphs.

A video presentation of the water quality trials with Kronoberg school as CeLeKT (2010b). The video is presenting the process made during the inquiry-based activities, which is presented in chapter 4 of this thesis. The prototype system that this thesis is based on is available as Johansson (2010).

1.1 Problem Definition

During the inquiry-based science learning, students collected large amounts of data. An important aspect of the learning process is the ability to reflect upon the data that has been collected. When there is a large amount of data the process of reflection and analysis of this data becomes very difficult. Today, many different web-based APIs are available that could support visual representation of data for providing better insights. With reference to above, in this thesis the main challenge has been formulated in the following question:

- How can the use of an interactive web-based visualization tool facilitate inquiry-based science learning?

In order to address the main question above, two following sub-questions have been formulated:

- What are the components for an interactive web-based visualization tool?
- What are the potentials of using visualization tools to support inquiry-based science learning?

In order to answer those questions the proper way to move forward is experimenting with teachers and students, while doing inquiry-based science learning. When the students come to that point after being out in the nature, collecting all the necessary values with their mobile devices, they will be able to gather it in one data set. This is important when they need be able to
discuss the information. By using the data that was gathered and presenting all the values in one screen, I believe it will then give a much better experience and informative perspective of the data. This tool will also be an important part of projects when it comes to the state when the students will discuss and compare samples from different areas. To do this I believe that a small tool is necessary. A tool that replaces the tables of data with animated diagrams, columns and geo-mapping presenting where the students gathered the data values. Therefore the efforts in this thesis have been guided in the previously stated questions.

1.2 Purpose and Goal

The purpose of this research is to explore, design and develop a web-based visualization tool, with the goal to present the data collected from mobile and sensor technologies. Furthermore, the collected data is comprised of GPS coordinates, images, users notes and values such as pH, temperature, dissolved oxygen and conductivity. The initial idea is to explore and combine different kinds of mashups and web technologies. This is in order to develop a tool that will be able to visualize the data.

This tool is developed with the focus to support teachers and students during the learning activities. Therefore some aspects that are considered are related to interactivity and user-friendly interface (Schwenk, et. al. 2009, p. 402).

1.3 Limitations

In relation to the solution of the thesis, there were some limitations in order for the completion on schedule. The limitations are:

- The solution of the thesis is a web-based visualization tool. This tool was developed in a prototype level, which means that it will have limited functionality.
- Besides from the use of Google Visualization API, no other visualization techniques have been used.
- The prototype has been developed using the JavaScript language. This could be considered a limitation, especially when it comes to combining different functionalities in the future.

1.4 Outline

The following chapters will explain in detail the steps from the chosen methodology, inspirations to the thesis and how the method was followed up.

Chapter 2 provides an overview of the chosen methods for the paper. The problematic issue was followed up by and carried out with a prototype. The chapter brings up this practice and discusses why it fits into this research.

Chapter 3, literature survey, contains a brief description about the research and how the project was grounded. It will also contain related works that were used as an inspiration to this thesis and the development of the prototype.
How the research process followed up the methodology is described in chapter 4. It describes the procedure of the development of the user tests and how the prototype evolved based on these user tests.
2 Methodological Approach

Method is a set of well-defined steps of a scientific inquiry, which allows for a better validation of the results. This list of steps ensures the validation of the results. Since this had to be so orderly I considered to have a very sound method. This will validate the outcome of my research effort. Throughout my research I have conducted a literature survey that identified which method is the best method of choice. This research is in relation to the CeLeKT group as well as the exploration of different technological tools that are used for prototyping.

As a part of this thesis a certain method had to be followed to be able to clarify the problem at hand. The method section is the prime way to reach the scientific knowledge and by using a method we separate the "science from nonscience" (Marczyk et al. 2005, p. 4).

Before the research began it was already aware that CeLeKT (2010a) was experimenting using modern mobile and sensor devices to facilitate science learning.

The inspiration for this research will be mentioned in 3.1 Related Work, in the Literature Survey part of this paper.

My research will have a focus on how the visualization should be made and therefore I will have to compare different types of programming languages. A comparison will be made between Flex and JavaScript to make sure it is compatible with the administration/client system that the LETS GO (CeLeKT 2010a) project is using. I also need to find out how well the technologies work with different types of mashups. It is important to make sure that I choose one that will fulfill the demands from both this research and the students.

During the research discussions were made with teachers and students who were a part of earlier research and had the chance to try the technologies. The teachers and students gave insight on which parts needed to be added to the visualization tool. The discussions revealed what was missing from the previous version.

These discussions were made on students and their teachers at Katedralskolan and Kronobergskolan in Växjö who are studying environmental science.

Throughout the project period numerous user tests were made. Based on the response from these user tests and discussions, a prototype was developed in close collaboration with the users. This was developed to answer the problem discussed in the introduction. This tool was tested to see if it would be possible to facilitate the students’ learning using this tool.

The prototype method was chosen based on which fundamentals were necessary for the users. By choosing to develop a prototype it will be possible to test it on the users. The testing would reveal the qualification it could have before applying the system. Therefore, it will be possible to get clear requirements and give the users the proper functions. Developing a prototype made it possible for the user to be involved in the process of making, which opened up new ways for the development of the prototype. The prototype will need to be flexible so that it can adapt to
everyone's needs. This is something that is not possible to decide from the beginning (Floyd 1984, p. 6).

2.1 Prototype

The prototype stage will be following the Prototyping method as found in Selecting a Development Approach (CMS, 2008). This approach will be the most useful, because the LETS GO project is already broken up into smaller parts and according to CMS (2008, p. 3) this will increase the overall approval by incorporating the user involvement. CMS also describes that this method is a combination of "more traditional development methodology (i.e., Incremental, Spiral, or Rapid Application Development (RAD))." (CMS 2008, p. 3)

Using this method forced the prototype to continue in the cycle until an accepted version was completed. The steps (see Figure 2.1) show that when an initial investigation has been made the prototype will continue to evolve. It will continue to be tested until the user tests reveals that the prototype is at its final stage.

![Prototype Diagram](image)

Figure 2.1 Prototyping (CMS 2008, p. 3)

- **Initial Investigation**
  The first step in the prototyping method is to do an initial investigation. What has already been made, how did the previous user tests turn out and what parts does the prototype need? It will be of importance to find out what others have done and if their solutions can be combined as a part of the new prototype. This means collecting reused material from previous user tests and prototypes, and taking prior knowledge and possible features into the up and coming version.

  The first steps before starting the prototype are brainstorming ideas, drawing illustrations and gathering the different technologies in order to develop a solid complete design.
• **Requirement Definition**
  In this stage it was important to find out what the requirements and needs of the prototype were. To get this knowledge multiple user tests were completed from two high schools, Katedralskolan and Kronobergsksolan.

  Together with the users, the prototype received the demands and requirements that it needed to evolve into a more complete application. As the prototype evolves, it will be needed to look back and make sure the incomplete or/and missing features are fixed and are added according to the response from the user tests.

• **Coding, testing...**
  During the development a lot of coding had to be made since multiple visualizations were necessary. The visualization tools that were made were all based and carefully aligned with the response from the requirement definition.

  An essential part of programming is to make sure the application works in the user’s client. Since this application is web-based and is limited to the desktop, it then requires testing in a web-browser.

• **System Design**
  In this stage it might be necessary to create a design with no functionality. This in order to have a better focus and separate programming and design. When the coding part is at a stage when no more functionality can be added before it has been tested, then the design can be implemented. This part will take place just before a major user test will occur.

• **Implementation**
  When the prototype has come to such a stage when both the users and the developers feel satisfied, the implementation stage can take place. All the different parts should be included when this stage is complete. This includes all the parts from the prototype and a technical documentation of the coding stage.

• **Maintenance**
  Maintenance and a final implementation will not be the main goal for this research. The goal is to find out if the prototype can help students. Maintenance will happen after the research is complete and when the final implementation occurs. This also depends on how successful the prototype is.

2.2 **Technologies**

The base of this research will be to explore how visualizations can be used to support learning. Google lately has become well known for offering a wide selection of different APIs. Therefore the focus of this thesis will be to explore and adapt different visualization techniques from Google Visualization APIs. The data collected during the learning activities, is stored in Google Spreadsheet. By using Google Spreadsheet it will make it easier to connect the data from the ODK (Open Data Kit) package. It will also make it easier combining code examples from
Google Playground (2009) (a place to test different visualizations). Since a lot of them already is based on the use of Google Spreadsheet as a dataset.

The decision to use the programming language JavaScript came due to the amount of free examples found at Google Playground (2009), which is made for JavaScript.

The choices were also made more or less based on the comparison between AJAX and Flex/Flash made by Franco (2008). Parts from his documentation were placed in a new table (see Table 2.1). The thoughts were of how much capability the visualization tool needs to have to accomplish the necessary events. Together with the table information, it made it clearer that JavaScript would be able to accomplish this.

<table>
<thead>
<tr>
<th></th>
<th>AJAX</th>
<th>Flex/Flash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animation</td>
<td>Simple</td>
<td>Rich</td>
</tr>
<tr>
<td>HTML Rendering</td>
<td>Fully supported</td>
<td>Limited</td>
</tr>
<tr>
<td>Video &amp; Audio</td>
<td>No native support</td>
<td>Supported</td>
</tr>
<tr>
<td>Development</td>
<td>Multiple free editors</td>
<td>$500 Flex Builder</td>
</tr>
<tr>
<td>Environments</td>
<td></td>
<td>$700 Flash CS4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Any free text editor</td>
</tr>
<tr>
<td>Vector Graphics</td>
<td>VML &amp; SVG</td>
<td>Supported natively</td>
</tr>
<tr>
<td>DOM Control</td>
<td>Supported</td>
<td>No native support</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Limited</td>
<td>508 compliant</td>
</tr>
</tbody>
</table>

Table 2.1 AJAX vs. Flex (Based on Franco 2008, p. 2–3)

This table compares and contrasts AJAX and Flex/Flash. Shown are the different features that each technology supports. The way that AJAX was presented, instead of just JavaScript is because the examples taken from the Google Visualization API is based on AJAX. AJAX was chosen over Flex/Flash because the users need only simple interaction, almost no animations and all the examples explained previously.

- Furthermore, even though Flex is capable of creating richer and more powerful animations, the use of SVG (Scalable Vector Graphics) or VML (Vector Markup Language) would be more than enough for the simple interaction needed for the users (Franco 2008, p. 2).
- HTML5 is slowly making its way in the modern open source web-browsers. Meaning it is still under development and is compatible with a few web-browsers. Compared to earlier versions is video/audio natively built-in. If video and/or audio in the future would ever be a desired ability, HTML5 will offer this in a simpler way, compared to the processor power that Flash requires.

The chosen technologies will support the implementation of information visualization techniques. The process of information visualization (see Figure 2.2) starts with the data from the mobile and sensor devices. The data is applied to the visualization tool. This makes it possible
for the users to give their opinion after interacting with the tool (Wakita & Matsumoto 2003, p. 29).

Figure 2.2 Process of information visualization (Wakita & Matsumoto 2003, p. 29)

2.3 Usability Aspects

The usability aspects have been carefully followed by discussions with teachers and students and observations during the trials. Sharp et al. (2007, p. 25) defines usability as a goal to find the capabilities of a product and to see if it can or cannot be modified for the better. Sharp et al. separates usability into three parts:

- Efficiency: “time to complete a task”
- Learnability: “time to learn a task”
- Memorability: “number of errors made when carrying out a given task over time”

Sharp et al. (2007, p. 25)

Throughout this trial students and teachers and their interactions with the developed prototypes have been carefully observed. Their remarks and requirements have been an important input for the design and development of the interactive web-based visualization tool. Nevertheless, I have not conducted a formal evaluation; it is only based on my observations of their inputs. This has helped the prototype change for the better.
3 Literature Survey

As mentioned in the methodology section, the literature survey will be about related work. The related work gave inspiration and was necessary to give a better understanding of what was needed to be done. This part will also give a brief description of what the subject is about.

This thesis is based on previous research with the project LETS GO. In Vogel, et al. (2010, p. 4) they describe that when the students came back to the lab they were able to prepare the samples they gathered and analyzed the data. In doing so they were using a built-in camera and were recording notes with a digital pen.

In Vogel et al. (2010, p. 5–6) a prototype was created to present the collected data. This visualization tool was compiled with two techniques, a timeline and a time plot. They were conformed with Google Maps API and with a focus on the temporal visualization (Vogel et al. 2010, p. 5–6).

The featured prototype will have more of a focus on the visualization parts but will be working side by side with the previously developed tool. This previously developed tool will not added in entirety to the featured prototype, but certain parts may be considered, such as the map. Therefore they can be both tested on the students at the same time. From this it will be shown how each tool stands out from the other and also to figure out which parts need improvement. The featured prototype will also make it clearer, compared to the previous prototype, to make a comparison between two locations. All the data will be presented at once to the students, instead of having to click on every individual pin.

3.1 Related Work

These additional projects have given inspiration for this thesis. A brief overview will be given of these related works, including The Mannahatta Project, Gapminder World, LETS GO, Personal Inquiry and CoVis.

The relationship that The Mannahatta Project and Gapminder World have to this project is the use of similar technologies that this project wants to use and how the outcome is expected. They also have a common goal, which is to use visualizations to present their data.

CoVis was an early trial to see how the use of such technologies could be used in the classroom. The LETS GO and Personal Inquiry projects both followed up with similar approaches and the uses of different technologies to encourage and challenge the students.

3.1.1 The Mannahatta Project

The Mannahatta Project is a project where they explore and show images of how New York would look like before it was a city, all the way back to 1609 (The Mannahatta Project, 2009).
They use a Geographic Information System (GIS), which is a system that includes mapping software, to visualize how the city has changed over these 400 years. Sanderson and Brown (2007, p. 549) present how current GIS data made it possible for them to do an ecosystem comparison of the island (Sanderson and Brown 2007, p. 549). By using GIS from the American Revolution they are able to visualize how Manhattan used to look like, by layering different GIS layers on top of each other (Sanderson 2009).

Another aspect Sanderson brings up in "Eric Sanderson pictures New York -- before the City" (Sanderson 2009) is how to present animals habitats by mapping their needs. Here he maps out different subjects and elements of habitats and then visualize them as a social network. Thus creating lines connecting species to species, creating a "Mirror web". This reveals and proves how all the animals are linked to one another (Sanderson 2009).

### 3.1.2 Gapminder World

Gapminder Foundation is a Swedish organization that is working towards world wide sustainable development, with hopes to help accomplish the United Nations Millennium Development Goals. Hans Rosling, co-founder and spokesman for Gapminder Foundation, is a professor of International Health and is very well known for his work at Gapminder. He uses innovative thinking to portray his ideas. He uses simple objects, such as Lego, to help the general public understand what he means and what he want the outcome to be (Gapminder 2010).

Gapminder World is a web-based service for displaying different time series of development statistics, such as how the income has changed over the years in one or multiple countries. The client is based on Flash and can visualize major global development trends with animated statistics and colorful graphics. Their main idea is to present the development trends of the world, though any individual can use it for personal use (Gapminder 2010).

### 3.1.3 LETS GO

The LETS GO (Learning Ecology with Technologies from Science for Global Outcomes) project uses several types of technologies, such as mobile multimedia technologies, sensors, digital maps and interactive visualization tools. With the use of these technologies they hope to achieve new ways of learning in accord with mobile science learning. Their goal is to help students in grades K-12 to be able to experience and learn from the environment in a fun and exciting way, with the help of technology. The idea of the project is for learning apart from the basic classroom structure. With this opportunity, the students will have a chance to use new technologies individually and in small groups (CeLeKT 2010a).

Linnaeus University (formerly known as Växjö University) and Stanford University are working together to assess, improve and research in high school environmental science classes. The project gives the Swedish and American students a common website to share data and research (CeLeKT 2010a).
3.1.4 **Personal Inquiry Project**

The Personal Inquiry (PI) project was a project that was working with a location-based inquiry educational system. The project had a goal to facilitate an eight-week GCSE Geographical project, which was tested on 78 students in a UK secondary school. With the use of combining mobile and web technologies they had a goal to see how efficient these technologies could be, not only in school, but also out on the school trips and at home (Collins et. al. 2008, p. 1).

Like the LETS GO project, the PI project combines different types of technologies, such as laptops, cameras, GPS devices and sensors. This makes the typical classroom stand out more (Collins et. al. 2008, p. 4).

A web application was created to facilitate the students while analyzing the gathered data. This tool was programmed in the PHP language and gathered its data from a MySQL database. For every location where the students had collected data they were required to insert their GPS-position. They were also required to record other values, such as wind speed and air temperature. They had to record notes about land usage, current weather and if anything could have affected the data (Collins et. al. 2008, p. 4).

The application also made it possible for the students to download all the recorded data into a csv file and also a kml file. These files made it possible for the students to see their accomplishments in any spreadsheet program and Google Earth (Collins et. al. 2008, p. 5).

3.1.5 **CoVis**

CoVis (short for Collaborative visualization) project is using visualization tools in combination with scientific cognition and with a focus in a collaborative educational way (Pea 2002, p. 1).

CoVis aimed to transform the traditional classroom and make it go from "learning-before-doing" to "learning-in-doing". They wondered how they could enhance science education through the use of different technologies. This was a new idea at the time, which initiated education over the Internet. Many teachers and students, across eleven states, participated. Each classroom was equipped with several desktop computers that had access to visualization and collaborative learning tools. Each student had access to their own web account and several of today common web tools (Pea 2002, p. 2–5).

Their main goal with the visualization and collaboration tool was for all students to be able to use it and to better understand what they were learning. The student active participation was also of great importance (Pea 2002, p. 6–8).

The visualization program created was called WorldWatcher and its purpose was to present students with scientific data in a way that makes complex data understandable. In the system there are data libraries that contain all of the WorldWatcher data, which enhance learning. This also encompasses certain datasets. These are "used in interpretive, analytic and expressive visualization activities" (Pea 2002, p. 9).
3.1.6 Summary

The goal that the first two projects have is to really use visualization to the fullest. This is in order to use a more powerful way to explain complex data to the audience. The three-following projects seek to make the classroom and its students to learn more by doing more. To make this possible they believe modern technologies, such as Mobile technologies and the web is the answer.

<table>
<thead>
<tr>
<th>Project</th>
<th>Digital Map</th>
<th>Interaction</th>
<th>Sensor</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Mannahatta</td>
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<td>Yes</td>
<td>No</td>
<td>Flex</td>
</tr>
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<td>Gapminder</td>
<td>Thin</td>
<td>Yes</td>
<td>No</td>
<td>Flash</td>
</tr>
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<td>LETS GO</td>
<td>Google Maps</td>
<td>Yes</td>
<td>Yes</td>
<td>AJAX</td>
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<td>Personal Inquiry</td>
<td>Google Earth</td>
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<td>PHP</td>
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<td>CoVis</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
</tr>
<tr>
<td>The Present Prototype</td>
<td>Google Maps</td>
<td>Yes</td>
<td>Yes</td>
<td>Javascript/AJAX</td>
</tr>
</tbody>
</table>

Table 3.1 Related Work Comparison

This thesis will, compared to the described table, take use of Google Maps, have user interaction, collect data from senior devices and use the programming language JavaScript to interact with the Google Visualization API.
4 Prototyping Efforts

This chapter presents a description of the efforts made related to the trials. The chapter also describes the follow-up of the method. During the trials a web-based visualization tool was used in order to be able to validate the problem described in the introduction of this thesis.

4.1 Initial Investigation

The first visualization prototype that was made in the LETS GO project (see Figure 4.1) included a timeline and a map. The tool made it possible for the user to drag the timeline in order to change the dates. The timeline was also interactive with the map below it and was updating simultaneously. So if any data had been collected from the database, it would be presented both in the timeline and on the map. The values that had been collected were presented when the user either clicked on a link in the timeline or on a pin marker in the map.

This mockup became the base of the initial idea, since it was the first and only tool to compare with from previous trials. The user was presented with all the data and the location of the sampling, but the mockup lacked the ability to visualize the data. It was hard to be able to compare the different locations and values, since the user had to click on every pin marker or link.

![Previous Visualization Prototype](image)

Figure 4.1 Previous Visualization Prototype
4.2 Initial Idea

Before any programming was done or any decisions made about how the combination and use of API's, the idea of how the prototype was going to turn out was printed out on a paper (see Figure 4.2).

The sketch was based on the knowledge that was given during the initial investigation stage and during the planning of this thesis. The first sketch included the two main parts from the previous prototype. This included a timeline that was updating the values of the visualizations below it. The idea for the map was that it was supposed to be integrated with the visualization charts. If the user clicks on a pin on the map, the charts would respond.

In previous user tests with LETS GO, a Livescribe pen has been used. This pencil was recording what the students said and wrote. This, together with pictures, had a big focus.

At the bottom three visualization charts would be placed, presenting the values the students been collecting, such as temperature and pH-values.

![Figure 4.2 Paper Prototype](image)

4.3 First Functional Prototype (Version 0)

The first coding was more of a practice and understanding of how the Google Visualization API worked. This version counts as the first prototype because it was more than a copy of a tutorial.
This version was built with a base of three combined visualizations and a simple table displaying values collected from the data set.

It was decided early on that the records from the *Livescribe* pencil would not be presented in the prototype. The pencil did not fit into the visualization part and it was not planned to be used in future user tests.

At the moment it did not seem logic to present the data in more than two chart versions. Also the timeline did not yet fit into this prototype because there were so few different dates that had been saved into the dataset.

<table>
<thead>
<tr>
<th>Seq</th>
<th>SubmissionDate</th>
<th>Temperature</th>
<th>DissolvedOxygen</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tuesday, March 2, 2010 11:45:40 AM UTC</td>
<td>3</td>
<td>2</td>
<td>5.8</td>
</tr>
<tr>
<td>2</td>
<td>Wednesday, March 3, 2010 9:49:58 AM UTC</td>
<td>4</td>
<td>1</td>
<td>6.4</td>
</tr>
<tr>
<td>3</td>
<td>Wednesday, March 3, 2010 10:16:42 AM UTC</td>
<td>5.4</td>
<td>3.4</td>
<td>7.5</td>
</tr>
<tr>
<td>4</td>
<td>Wednesday, March 3, 2010 9:49:47 AM UTC</td>
<td>2.3</td>
<td>2.2</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>Wednesday, March 3, 2010 10:16:35 AM UTC</td>
<td>1.5</td>
<td>1</td>
<td>6.6</td>
</tr>
</tbody>
</table>

Figure 4.3 First Functional Prototype

4.4 Case 1: Katedralskolan (Prototype 1)

Katedralskolan was the first part of the cycle from the prototyping model. There were not more than five groups stored in the dataset. This means that the development of the prototype had to remain in the speculative mode.

4.4.1 Learning Activity

On February 17th there was a class of about twelve students at Katedralskolan who were split up into four groups. Each group was handed a sensor collecting device. The assignment was to compare four kinds of water samples. The purpose of this comparison was to come to the conclusion of which water is the most suited for a perch to live in. The only information the teacher gave the students was that sample one and two had high temperatures, number three was at room temperature and the last one was +5 °Celsius.
The whole lesson was picture documented by the students, using an Android mobile device.

The conclusion after discussing with their teacher about previous tests with the mobile devices and visualization tools was that he wanted a clearer way to know exactly where the collection of data had been sampled. He pointed out that the GPS position was unable to show for example which tree the value had come from.

4.4.2 Presentation of First Activity

The first prototype was presented on March 17 at Katedralskolan in Växjö, to a class of about 12 students. The presentation included parts from the ongoing project LETS GO.

Both visualization tools were presented. The previously made prototype was first presented (see Figure 4.1). The students were fond of the Google map, presenting where the pictures and data had been collected. The pictures were something that still was not included in this thesis' prototype. Due to the positive response, pictures would have to be included.

The focus of the prototype of this thesis was on the map, line- and pie charts. Of all of the charts, the line tool was the most successful one. They approved the idea that they could see how the different collections from each group were visualized as lines. It appeared that the teacher had it easy to create discussions about the chart. The discussion was about how the students' temperature results differed so much from each other. This is exactly the result that was wanted, to make the students see the data in a different way and to create a discussion about it. Alone, the numbers do not say much, since there is just a 2.5 degree Celsius difference between the highest and the lowest numbers. By presenting it as a graph instead of table, it gives a more in depth visualization.

The last graph, presenting the time spent on the task at hand, had negative reviews from the students. They quickly disapproved the idea of being timed, because they showed signs of nervousness. Time was never a part of the task, it was just the best way to display the pie chart.

The annotated time line was still in the prototype but it never really came in to focus since it needs more data over time if it is ever going to be efficient. Again, this could therefore be something to consider for future work of the project.

The conclusion of the first user test is that the prototype should develop the map and include more features to it. The line chart will be kept as it is, or maybe ever consider giving it more space. The pie chart is going to be removed; it does not look like it could present any other data from the data set.

The teacher also made it clear to the students that a tool like this could be used in the future. For example if they want to use it in a year. It could then be good to be able to go back again. It would also be nice for the possibility to see the weather from the pictures, the location where they were and the data all in one place.
4.4.3 Prototype Effect From User Response

The way of displaying the time to complete a task was quickly removed from the prototype. The pie chart also did not seem to fit in anymore and was replaced with a temporary column chart. The annotated timeline was also removed, since it at the moment did not present any valuable information.

4.4.4 Second Functional Prototype (Version 1)

The first real version of this thesis’ prototype (see Figure 4.4) was a combination of different visualization tutorials from Google Playground. Presented in Figure 4.4 there were still not any real user interactions or user tests. It was still under speculation and the idea stage of what the user could need in the classroom. The prototype contained five different visualizations:

1. Table - This table displayed the database in rows and columns. The table was also interactive with the Pie example, so if you clicked on a row the selected slice created an animation. The table in this version was representing the last loaded visualization, which would be the pie chart.
2. Map - A map displaying the groups' location when and where the data had been collected.
3. Pie - A pie chart that visualized the time it took each group to complete the task at hand. In the previous version the slices were presenting different temperatures, but using temperature in the pie did not give a very good perspective. Therefore it seemed more logical to use it to present the time each group took to complete the task as hand.
4. Line - Displayed three kinds of collected data: temperature, pH and dissolved oxygen. It drew a line between the different dates that they had collected.
5. Annotated Time Line - Displayed each group in a time line. This was not successful at the moment, because there were not enough dates in the database. So the annotated time line could be something that could be brought back in the future after more user tests had been made.
4.5 Case 2: Kronobergskolan (Prototype 2)

The second cycle took place at Kronobergskolan, Växjö. Compared to the previous case, this would have more events planned. With more events, it was easier to see the connection and interactivity between technology and students.

4.5.1 Technical User Test (Trial 1, In-door)

On the 7th of April, three classes at Kronobergskolan in Växjö started a big project together with the LETS GO project. The goal was to see how the students managed to interact with the technologies in the same way as the previous school had to do. The plan was to split up the project into three trials. Trial one and two would be practice for the final trial. The event would be over a three-week period with classes consisting of about 50 students. The technologies they had to use were Pasco Spark and an Android mobile device.

On April 8th the students got to try out and get familiar with the technologies.

The first trial was presented on the 9th of April and took place inside of Kronobergskolan. The trial was that they would test five different samples, which contained:

- Melted snow (from one of the teachers’ backyard)
• Seawater (Lagunen, Växjösjön)
• Residual water from a dishwasher
• Baltic Sea Water (Ystad)
• Tap water

The three classes were split up into five groups. The students were given the task to sort out the cups, 1-5, which contained what test.

The samples were tested one sample at the time, using a sensor collecting device. At the same time the values were recorded into the mobile devices. Every test that was saved into the mobile device contained the data values and some of the students’ notes and pictures that the students had taken. Every water sample had to be taken one by one, since the ODK program had to start a new session each time.

When a group was finished with the task, all the data was sent away to the chosen dataset. There was some problem uploading due to poor network at the school. Also, if any data was uploaded, the ODK program is built to erase it from the mobile device. To be on the safe side the remaining groups started to write down the values on a piece of paper. So they could be able to discuss the difference between the values in a later part of the lecture.

The groups that did not get their data erased were able to use the mobile device during the discussion. Most of the students chose to use the paper (see Figure 4.5) due to how hard and inconvenient it was to compare between the different samples in the ODK program. The students had to read one value, leave it and then go to the next without having the previous value next to it.

This showed that the phone was not going to be enough for the students during the phase when comparison was done.

Figure 4.5 Student Notes
4.5.2 Technical User Test 2 (Trial 2, In-door)

The second trial was introduced on the 14th of April. The task given to the students was to find a home to Nemo, a clown fish. As in the previous trial, the students consisted of three classes, with the same groups and activity. This time the groups were presented with three different water samples.

At the end of each lesson the teacher collected all the values from each group and presented those on the whiteboard (see Figure 4.4).

In a discussion with one of the teachers about how he felt the discussion had gone with the whiteboard as presentation, it was clear that getting all presented at once would be at great help. It was also clear how it should be presented. If the data presented was from the same day, he could then accept the use of a column chart and not a line chart.

Secondly and the most important thing when discussing with students was to be able to see the mean value. This was something that he had tried to find out as soon as he had written the figures on the board and was in the process of discussing it.

Lastly was the discussion with the teacher that brought out the idea that he would like to be able to filter out values such as temperature and pH.

![Figure 4.6 Whiteboard](image-url)
4.5.3 Filtering and Version 2 Planning

During these user tests the participants noticed the potential and the need to be able to filter the data. This was due to how much data had been pushed into the data set and that the amount of groups had been raised drastically.

If a continued use would be possible for the prototype to stay as a helping tool for the student it would be necessary to have at least the following functions:

- Since we had collected data from different schools, both in- and outdoors, it would have to be possible for the user to select the data set where their data was stored (see Figure 4.7)
- To be able to filter between groups, dates and schools.
- To be able to select and decide for oneself what kind of visualization chart you want to present the data in.

Based on the discussion with both the teachers and students there were different opinions and choices of charts. The students at Katedralskolan were pleased with the presenting of a line chart and the teacher at Kronobergsksolan seemed to have more of a need for a presentation in the form of columns. Therefore the option was to be able to decide for oneself.

The filter process was the beginning of a new version of the prototype and a new design (see Figure 4.8) would be necessary to make the new features available.

![Figure 4.7 Dataset Filter](image-url)
4.5.4 Final Technical User Test (Trial 3, Out-door)

The third and final trial about the technologies was taking place outside, on April 16th. The goal of the day was to let the students collect and test natural water. There were two lakes where the sampling would take place, Växjösjön and between Northern and Southern Bergundasjön. Växjösjön had four spots where the samples should be taken. The three classes were split up into 15 groups. 12 of these were located around Växjösjön and each group had a route of two of these locations. The three remaining groups tested the water at Bergundasjön. They had the task to go between the northern and southern parts of the lake to see if there were any differences.

The collection of the data was made the same way as in the previous trials. The trial and the efforts made by the students turned out positive and was presented in the visualization tool. The map resulted in a very effective display of where all the groups had been (see Figure 4.9). The picture collection also turned out successful. The students were supposed to take pictures of where the samples took place and what could affect the result of the samples.
4.5.5 Presentation and User Test on Visualization Tool

On the 21st of April the final lecture was for the students and the task at hand was to discuss trial 3 (see Figure 4.10). Each class was given a presentation about the second version of the prototype. To be able to use the prototype each group was given a Classmate PC. The presentation included: the key components of the tool, the fact that the table chart was linked with the map, how the filtering worked and the special functions with the Classmate PC.

This was the very first real user test that was done using the second version of the prototype. One problem that occurred was the screen size of the computers. It was also hard to understand where each sample was taken, using the map. Therefore the groups and location were written on the whiteboard (see Figure 4.11).

The response from the teachers was mostly about missing features, such as the mean value. In discussion with a teacher he suggested that it should be possible to choose certain values from the tool. For these values is should then be possible to present the mean value.

Also as noticed by observing the students, was how difficult it was to see where the actual value was sampled. This was an important need, not only to know where it was sampled, but also to be able to filter and group the different positions. For example, to be able to take group A's position and compare only those values.
The second version included an interactive table view. Surprisingly was how appreciated it was. It did not replace the remaining charts; it was more of a good asset combined with other visualizations. The students went between the table view and another chart. The table gave the exact value, while such as the column chart was able to give the students a good overview and comparison between different groups.

Overall, the previous user tests revealed the need of being able to filter the data. Without the well-defined filtering system built in the prototype, this would not have been a very positive experience. It was necessary for the students to be able to only see their own group and compare it with a few others. The dataset from trial 3 included 73 different uploads from the mobile devices. Displaying this in a chart was only presenting a blur of colors.

Figure 4.10 Prototype in use
4.5.6 Final Prototype (Version 2)

The final version of the prototype (see Figure 4.12) included an implementation of the system design, a filtering menu, three visualization parts and a container for images.

The ability to be able to select between data sets and schools was decided to be removed and put on hold. This was due to not make the students confused during the upcoming presentation and user tests. The purpose of the user tests would be to validate the effectiveness of using visualizations. At this moment, the tool was not supposed to be used to compare the results from previous schools. For the user test, the interesting feedback would be how they used the tool to discuss their data. The possibility to select schools is something that should be done before the user enters the client. This could be seen as a future work. Therefore, the filtering of schools was replaced with being able to filter data types, which includes temperature, pH, dissolved oxygen and conductivity.

Lastly regarding the filtering, compared to the previous versions, was the possibility to select multiple groups and data types, to display and compare the different values.

The three visualization areas contained a map, a main and a secondary area. The main area, directly connected to the filtering system, received more space. Added to the filtering part was a chart icon, containing five different ways to visualize the data. Lastly was the third and
secondary area, in a scatter plot form. This visualizes how the temperature changes when the pH rises.

Figure 4.12 Final Prototype, Version 2
5 Technical Implementation of the Prototype

The prototype is basically built on the combination of different visualizations found in the Google Visualization API. The tool is based on the programming language JavaScript.

The process of the visualization is a combination of different mobile, web and sensor technologies. This interconnection is illustrated in the conceptual architecture (see Figure 4.13).

![Figure 5.1 Components of Interactive Web-based Visualization Tool](image)

5.1 Dataset

As presented in previous part of this thesis, all the data would be stored in dataset. By using Google Spreadsheet as our storage, it made it easier to interact with the ODK application placed in the mobile devices and collecting the data in the different visualizations from the Google Visualization API. Some benefits using Google Spreadsheet for storage of data is:

- The possibilities to easy share a document with anyone who might be part of a project. Visually present all the data and even give them the possibility to edit the document.
• You don't need to install a MySQL or a similar database.
• You don't need any special knowledge to understand Google Spreadsheet.
• It is free.

5.2 Technical Approach

This is a technical documentation of the visualization tool called "Green Lab". The project is a part of this thesis and is a prototype. The name Green Lab was based on its main purpose, which is that it is for the users to use during the time of this thesis, which was for the environmental science learning. "Lab" was supposed to be a temporary name while the tool still was in a prototype stage. It is now based on that the users use it as a support tool during their own trials.

To be able to develop the visualizations, Google Visualization API was used, which offers many different examples. The tool is allowing the user to choose between seven different visualizations, including a map and an interactive table. It also presents the pictures taken during the trials. This with the use of jQuery as a base presents them along with using the plug-in FancyBox.

The coding part was planned to be as object-orientated as possible, meaning as much as possible should be able to be reused. Due to the lack of time some parts had to be compatible only with this prototype. JavaScript does not have a built in way of defining a class. There are three ways of simulating a class, namely: a normal function, JSON and "Singleton using a function" (Stefanov 2010). The prototype is built on the JSON version, due to the comfortable structure and that it felt as the most similar to a actual native class structure, such as found in for example PHP or Actionscript 3.0.

5.3 Software Components

Files: index.html, style.css, dropmenu.css, div.js, filter.js, main.js, visualize.js, dropmenu.js.

The prototype is built upon five classes (see Figure 4.13). The client (index) requires a positive callback from the Google Visualization API, to make sure everything has loaded correctly. The user interacts with the filtering and decides what should be presented in the Filter class. The Main class is used to set a queue for all the visualizations that should be presented and also is the link with the Visualize class. Visualize is the base between the seven chosen visualization retrieved from the API.

Client
The first thing that has to be done is to decide which visualizations we want to load from the Google API. google.setOnLoadCallback() is used to make sure everything has loaded correctly and nothing should be done before this function is complete.

Filter
This class has three important functions;
1. Initializes the list of charts available for the user.
2. Sets chosen database, which the query will call to.
3. Initializes the filtering menu. The menu displays and let the user filter between groups, dates, schools and data types.

**CurrentQuery**
Has a close connection with the filtering class. Sets and returns the current query.

**Div**
Is used to add and delete the loading database layer.

**Main**
Is used as a small connection between the Filter and Visualize class. Make sure all the current visualizations are loaded. Since it is a connection point, it also controls the possible filtering updates the user makes.

**Visualize**
Controls all visualizations. It has a direct connection with the Google Visualization API.

For a more detailed presentation of the connections between the components, see Appendix A-Architecture Component Structure.
6 Conclusion

In this chapter there will be a brief conclusion on the parts that have been described in this theses. It will bring up the final results of the user test and the effect they had on the prototype.

With reference to the first question, a conclusion can be made that such learning activities as described in previous sections of this thesis could be a possible way for integrating interactive web-based visualization to support learning. This has been done by providing students with a deeper insight into the different sensor values that they have been collecting in the out-door activities.

The components for building such a system have been described in section 5 Technical Implementation of the Prototype and in Figure 4.13 Components of Interactive Web-based Visualization Tool. This shows that a complete system would not be possible without the technologies of mobile clients, web-servers, data set storages and chosen API’s.

Based on my discussion with the teachers and through personal observation of how the students integrated with the visualization tool in their science education, I can suggest that visualization proves to be an important aspect for supporting inquiry-based learning activities. It can be seen in a data table that the teachers and students have actually made while comparing their values. A system that can be done automatically, saves time and enhances learning will benefit the students.

6.1 Discussion

The user tests were mostly based on the use of mobile technology and sensor devices. This gave a strong insight into how the use of a visualization tool could be helpful. It was soon discovered that although the students had all this technology available, they still chose to use pen and paper. This means that something was missing and the user experience was not good enough. Therefore, it was proved that a separate tool to visualize data and assist students during the discussion phase was necessary.

The final user test, using the prototype, shows that it filled a lot of the holes that were missing before. It also showed that more work would be necessary to fulfill the students’ needs. It was noticed that the usability of the prototype needed to be compatible with different types of screen sizes. The students had problems using the small screens that the Classmate PC’s offered. The small screens forced the students to do unnecessary scrolling, both horizontal and vertically. It will also need to be compatible with larger displays that should be able to give a more powerful and complex view of the visualization.

A result from the final user test was the map is a powerful resource. The students’ efforts are pin marked on a map, which is using GPS technologies; this is then emphasizing what they have done. To use this in the best way, the teachers had noted a large confusion in all of the masses of pin marks. It was hard to see the direct connection of the data on a chart and the location where it
was sampled. This will have to be dealt with using a well-defined filtering technique, so that only necessary data is displayed.

Overall, the user tests have made it possible to develop the prototype and to find the desired functionality. The students found the use of the prototype interesting and compared to the previous method using pen and paper. This fulfilled their needs during the discussions. The feedback that they gave evolved the prototype from the early stage to what it is now. In the beginning, this gave the user very few options of visualizations, to the option of multiple sets of classic charts in the finished stage. It also revealed the need for filtering data that the students at Kronobergskolan would have. It would not have been possible to find out this by speculation. Lastly was the surprising need of a data table. This was not used alone, neither did it replace the other visualizations and it was the perfect asset used that was combined with the remaining charts.

6.2 Future Work

For further use in the future it will be necessary to add on and further the development of the prototype. Previously a lot of work has been done with developing and testing the prototype. In order to be able to improve the developed prototype, the following guidelines will need to be taken into consideration:

- **Filtering - Schools:**
  If the prototype will be used for more than one school and more than one class, the filtering of the schools has to be put back in. The filtering cannot be a part of the interface of the prototypes; due to the risk that it could cause confusion to the students. A student does not attend several schools, which is another reason why it cannot be a part of the interface. The best way would be to place the different options of schools on one page before the user reaches the main interface.

- **Filtering - Maps**
  Currently the filtering was only triggering the main visualization. There was a big demand from the teachers that the map especially needed filtering. Since Case 2: Kronobergskolan was sending in so much data to the spreadsheet, it created a mass of pins in the map. The filtering has to either filter different areas of pins or/and let the user select which groups should be displayed.

- **Event-Based / Interactive User Interface**
  The second part that was noticed missing, mostly from the developer and project leader, was the lack of interactions between the different visualizations. A feature should be that if the user clicks on, for example the column chart, the map and scatter plot should trigger the same information.

- **Collaboration – Chat Room**
  Collaboration was something that we tried to work with in this thesis. During the report there were some efforts in adding a type of chat room or interaction between the students. The aim was to place the chat room next to the visualizations so that a discussion could
easily take place. There had to be a well-developed chat room, so that the students did not choose a desktop alternative, instead, such as Microsoft Messenger or Adium. The possibility to have it on the same place as the tool would be:

- They do not have to switch between programs.
- Everything would be at the same place. This would let them have all the data-values in front of them while discussing and they would not be as distracted.
- It would also be easier to connect and develop the next bullet point, drag and drop.

There were three efforts and attempts: Google Talk, XMPP jabber client and Google Wave. Due to the poor results and the lack of time, this had to be put aside.

- **Collaboration – Drag and Drop**
  If a collaborative chat room is developed, it needs to be useful enough to keep the user focused on it. A possible and interesting feature would be to give the user a drag and drop functionality. This would let the user be able to drag a picture or a whole chart into the chat room to share it with their friends.

- **Screens**
  Another feature is that it will have to adjust to both small and large displays. For future use and presentations of the prototype, it will be necessary that it can fit onto larger displays. Therefore the visualizations will be displayed at their fullest.

- **HTML5**
  As previously discussed in section 2.2 Technologies, HTML5 is being adapted to the modern web. This would offer new possibilities for the visualization tool. HTML5 would offer native technologies, such as video and audio. This means if future work would ever require such features it would be easier to implement them. Furthermore, it would not require combining additional technologies, such as Flash, to make this achievable.

Furthermore we plan to submit a contribution to the International Conference on Intelligent Networking and Collaborative Systems 2010 (INCoS 2010) with the outcomes of this thesis.

### 6.3 Reflection

Overall this thesis turned out well but there are some things that I could have done differently to speed up and better the whole process. These things include:

- As mentioned earlier in this chapter, the users tests with the visualization tool revealed a problem that the tool was not adjusted to different screen sizes. If I would have had more time and done it again, I would have done a small test on the devices a few days before they were planned to be used.
- Since the collaboration attempt was such a failure I would have waited, adding it in this version of the thesis. This would have saved me a lot of time, which could have been focused on other sections.
- During the second case with Kronobergskolan, the teachers wanted to be able to see the mean value between data sets. This was always on the agenda but was pushed aside due to more important parts, such as the filtering.
References


Franco, A. (2008). Flex vs. AJAX.


Appendix A : Architecture Component Structure