Statistics in "Ella Mathematics"

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Preface

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Abstract

"Ella Mathematics" is a web-based e-learning system which aims to improve elementary school students' mathematics learning in Sweden. Such an e-learning tool has been partially completed in May 2012, except descriptive statistics module summarizing students’ performance in the learning process. This project report presents and describes the design and implementation of such descriptive statistics module, which intends to allow students to check their own grades and learning progress; teachers to check and compare students’ grades and progress, as well as parents to compare their children’s grades and learning progress with the average grade and progress of other students. To better understand and design such functionalities, different mathematical e-learning systems were investigated. Another contribution of this project relates to the evaluation and redesign of the existing database model of the “Ella Mathematics” system. The redesign improved performance and reduced data redundancy.

Key words: Mathematical e-learning system, Descriptive statistics, Mathematical measures, Database model.
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1 Introduction

1.1 Background

Over the last years, e-learning systems have become more and more popular as they provide convenient and easy to use tools to support teaching and learning. Especially in mathematics education, it provides a lot of advantages compared to the classic way of teaching and learning. Such as the mathematical e-learning system allows students to learn mathematics anywhere and anytime, it also provides graphical and animated equations for students, etc.

Therefore, students Andreas and Angelica in Halmstad University planned to design a mathematical e-learning system in September 2011. The system is called "Ella Mathematics", earlier known as "ELEMENTA". It is a web-based application which intends to be used on computers, smart phones and tablets, etc. It provides the user interface which components with text, charts, and graphs and so on, as well as it can provide the functionality of communication for students and teachers. The aim of the system is to help the students of primary schools to learn mathematics as easy as possible, improve teaching and assist parents and teachers to check and monitor progress.

The project team completed the system in May 2012, except an overview module with descriptive statistics about students’ progress. Such module might students’ and teachers’ work. This descriptive statistics module can be seen and implemented as an independent part of the system. The project presented in this work describes the design and implementation of the descriptive statistics module as well as its integration into the main system.

1.2 Ella Mathematics

"Ella Mathematics" is a web portal that intends to replace the printed mathematics text book in the Swedish elementary school. When the mathematics education is moved into the digital world, the flexibility and adaptability will increase, such as by allowing students to choose when and where they want to study as well as enabling teachers and parents to monitor the student’s learning progress and grades more conveniently.

In 2011, the Swedish government revised the Swedish school system, which contained a whole new curriculum for the elementary school mathematics education. This has been the foundation for the development of "Ella Mathematics" and the design of three different users: student, teacher and parent.

"Ella Mathematics" has been developed with the pupil's mathematical knowledge in focus. "Ella Mathematics" provides a vast amount of reality-based exercises and movies. These tasks and movies are adapted both for groups and individual
students. The goal is to give students the best opportunity to get the knowledge required by their career and ease the teachers’ workload by giving support with group task and statistics. The user can login to "Ella Mathematics" where he or she can access to the Internet; through a cell phone, tablet, computer or interactive whiteboard.

With "Ella Mathematics", the pupil’s interests and motivations for mathematics will increase by a lot of interesting movies and different difficulty level tasks. "Ella Mathematics" aims to elevate the Swedish pupils to European top mathematicians.

"Ella Mathematics" provides many newer features and functionalities compared with other existing mathematical e-learning systems: such as it provides different areas in Sweden are representing different subjects; within each area, there are at least three sub subjects that contain tasks and movies. For example, "Ella Mathematics" intends to provide geometry and algebra two mathematical subjects for students, but it only can provide geometry so far, and it will add algebra in the future. In geometry subject, there will have three sub subjects, such as Stadens, Farmen and Baten. Within each sub subject, there will have several movies and tasks. When students finished their tasks, a grade will be got by the system. From these combinations, the statistics are collected with the results of the students.

1.3 Objectives

1.3.1 Investigate existing e-learning systems in mathematics education
While software engineers start to design any systems, it is essential to investigate the existing systems so engineers can find out similar systems. From these similar systems, engineers can know how they have organized the system, how they designed the database model and which features and functionalities they provided. Then the engineer can get inspirations to design database model and user interfaces, and so on. This would facilitate the design and implementation of the current work, therefore, improving the current system. This objective will serve as a background for this work.

1.3.2 Descriptive statistics module
The "Ella Mathematics" provides a lot of features. It allows teachers to communicate with their students, to give them exercises and to grade them. It supports different courses and study groups. To keep private data views are different from person to person; therefore a user login is required. To provide an overview of all different tasks, a visual, simple, statistical module is needed. The descriptive statistics module must be developed as a web-based application to be later on integrated into the system. This module must provide user interfaces with graphs or tables which can present students’ grades and their progresses, as users can check the result easily and clearly. It also provides the functionality of searching a specific student result for teachers. In this module, several statistical
measures are used: mean or average, mode, median and standard deviation. The mean or average can be used to describe the average grade by each student and each task. The mode can describe the most frequent grade. The median can describe the middle grade value of the entire grade set. The standard deviation can be used to present the dispersion of the average grade. Because of through using these statistical measures, teachers can clearly know about the distribution of students’ grades, the average grade, the grades of the most students gained, and the middle value of grades. There are different users’ profiles, such as students, parents and teachers.

- **Students**  
  Students need to see their own tasks’ status (pass, fail, unfinished), the number of passed tasks and the percentage of passed tasks.

- **Parents**  
  For parents, it is interesting to see the same thing as the children. Moreover, parents may want to know the average number of passed tasks and the average percentage of passed tasks.

- **Teachers**  
  Teachers have the opportunity to see the progress and results of all students in their class whenever they want. These results include the average grade, the dispersion of the average grade, the most frequent grade, and the middle value of the entire grades. These results are got by students and tasks. Additionally, teachers might want to see the percentage of passed tasks for each student.

### 1.3.3 Evaluate the current system design and implementation

The system might contain design and implementation issues related to its architecture and codes. Therefore we plan to evaluate the current system design and implementation, especially the database model. Furthermore, we will suggest solutions for problems that we might find.

If we find problems which involved system architecture and database model of the current system, such as product issues, technology issues, management related issues, etc [1]. We will propose a new and better database model for the company, that the company can improve its system later. The current database can be compared with the proposed model regarding data redundancy, speed and memory usage. With this comparing, the company might choose a better solution to develop its e-learning system.
1.4 Limitation

This project aims to develop a descriptive statistics module, delimited our investigation to just web-based e-learning systems in mathematics education.

We will evaluate the system design and implementation for such product issues and technology issues and so on [1]. If problems exist, we will suggest possible solutions but not implement them by ourselves. It will be up to the company to improve its system in the future.

1.5 Outline

The remainder of this report is organized as follows.
Chapter 2 presents the background information for this work and includes an overview about e-learning systems, particularly e-learning systems for mathematics education targeting primary- and middle-schools students.

Chapter 3 describes the methodology to achieve the proposed objectives, such as tools and methods required to setup the development environment.

Chapter 4 present achieved results, such as the user interfaces for the descriptive statistics module and possible solutions for issues encountered in the existing system.

Chapter 5 discusses and summarizes this work.
2 Background

2.1 E-learning systems

The e-learning system is a technology platform, which based on computers and networks to spread information. People can use e-learning system to obtain knowledge and skills immediately whether sitting in the classroom or not [2]. E-learning system extremely changes students’ learning styles, for example, students would like to learn knowledge whenever they want, instead of learning in the specified time [3]. With regard to the campus education, students can utilize electronically ways to learn academic contents at home. Such as web-based learning and computer-based learning, also the academic contents can be delivered by Compact Disc, Video tape, and television, etc. Compared to the traditional way of learning, the benefits of e-learning system are following:

- Open learning, which indicates that learning materials are available anytime and for free; there is no need to buy books and learning materials for students [3].
- Flexible learning, the e-learning system does not only help students to enhance their knowledge level, it also allows students to evaluate their study result through on-line assessments [3].
- Distance learning, students can learn knowledge anywhere (school, home and study center, etc). Especially for those who are disabled, they don’t need to go to a traditional classroom to get knowledge any more [3].

As e-learning systems rely on computers and networks, learners must have a computer and access to Internet, as well as some computer skills.

2.2 E-learning systems in mathematics education

E-learning systems have played a significant role in education, especially in mathematics education as it can provide visual and graphical explanations and animations to help students understand mathematical knowledge. Due to a number of areas (such as geometry, algebra, differential and integral calculus, etc) have been covered in mathematics, and practice is a more important aspect in mathematics learning as it can enhance students understanding. Therefore, a systematic learning in mathematics is needed.

With the increasing importance of mathematics education in recent years, the number of mathematical e-learning systems is rapidly increasing. The e-learning systems in mathematics are used in schools to improve students’ mathematics learning and teachers’ teaching.
The advantages of web-based e-learning system in mathematics are following:

- Knowledge resources are available anytime and anywhere.
- Students can propose problems and take exercises whenever they want.
- All students can discuss and solve mathematical problems directly through the Internet.
- As students finished their assignments, the system gives feedbacks immediately to students and teachers [4].
- Graphical and animated learning materials from e-learning systems can help students to understand the equations in the mathematical field.

2.3 Existing e-learning system in mathematics

Mathematical e-learning systems can be divided into four categories, according to different study levels:

- University
- High school
- Middle school
- Primary school

As regards to the systems for each area, we will introduce them by target, content, interaction and descriptive statistics.

2.3.1 E-learning system in mathematics for universities

The target of mathematical e-learning systems for the university is to improve the university students' mathematics learning [5]. When the students finish their exercises, the system can give feedbacks to them. For professors, they might check all students’ results and the averages if needed.

For example, "TU Delft LA-system" is a web-based mathematics e-learning system which is used by Delft University. The LA-system (Linear Algebra) of Delft is an interactive tutor system developed for high level mathematics. The system provides graphical equation writing. Professors can create exercises easily by selecting graphical menus. To solve exercises, the system guides students through the necessary steps [5].

LA-system aims to improve math skills for university students. If the student fails at the first examination, the e-learning system is capable to aid student's self study. The system offers a lot of exercises, as well as web lectures and solutions. Meanwhile, students are able to check their answers whether correct or not. In case of problems, students can request help from the system. This system can eliminate plenty of rewriting complex formulas and make students focus on solving exercises. Furthermore, the system can follow the student step by step and provide proper feedbacks when students are doing their tasks [5]. However,
the system in its current version does not provide the user interface which presenting the descriptive statistics for students, their parents and teachers.

2.3.2 E-learning system in mathematics for high schools
The aim of mathematical e-learning systems for high school is to help the high school students’ mathematics learning. E-learning systems can provide both learning and teaching. When the students have finished their assignments, the system can give feedbacks to students. For teachers, they might check all students’ grades and averages by this system.

For example, "WIRIS" is a web-based and global open-source e-learning system for mathematics. It is used in high schools. The aim of this system is to help high school students learn mathematics as easy as possible. Its features are online math formulas, visual editors and compatibility with touched devices [6]. However, it cannot provide the interface of presenting the descriptive statistics for students, their parents and teachers. The six main parts of this e-learning system are:

- "WIRIS EDITOR"
  "WIRIS EDITOR" is a WYSIWYG (what you see is what you get [7]) equation editor, which is based on JavaScript technologies to create formulas dynamically. The PNG images are generated by MathML (Mathematical Markup Language) [6].

- "WIRIS CAS"
  "WIRIS CAS" is a web-based computer algebra system, but also dgs (dynamic geometry system) is contained in this system. It is a calculation platform which covers mathematical fields from primary school to university [6].

- "WIRIS QUIZZES"
  "WIRIS QUIZZES" is a plug-in which provides various kinds of questions (true/false, multiple choice, matching answer, etc). Teachers can create dedicated questions quickly through "WIRIS QUIZZES" [6].

- "WIRIS WHITEBOARD"
  "WIRIS WHITEBOARD" is a platform which collects exercises and laboratory exercises; with "WIRIS" whiteboard and editor. "WIRIS" provides a friendly user interface [6].

- "WIRIS PLUGIN"
  "WIRIS PLUGIN" integrate "WIRIS EDITOR", "WIRIS CAS" and other web applications [6].

- "WIRIS HOSTING"
  Host "WIRIS" web based solutions in wiris.net servers [6].
2.3.3 E-learning system in mathematics for primary and middle schools

The goal of mathematical e-learning systems for primary and middle school is to motive the students’ mathematics learning. The e-learning systems can provide: learning, teaching, communicating and small games. When the students have finished their tasks, the system can give necessary rewards to them. For teachers, they might check all students’ results and the average by this system.

We will introduce three examples of mathematical e-learning system for primary and middle schools.

- **"IXL"
  "IXL" is a web-based e-learning system which used in primary school, evaluates students learning by exercises and performance reports. The aim of "IXL" is not only to help children to learn mathematics; it also makes children enjoy learning [8].

  The performance report of "IXL" can help teachers to find out the potential of students in mathematics. Teachers can trace students learning by using the reporting suite in "IXL", they also can assign homework and set up study goals for their students. When students make an excellent work, awards (ribbons or medals) will be given them to encourage learning [8].

  In "IXL", there are many interesting games provided for different study levels. These small games offer different tasks to students, as solved tasks give students score points. Therefore, students can learn mathematics with more fun [8].

  As regard to the user interface of descriptive statistics, "IXL" provides "state standard reports" for teachers and parents except students. With these reports, teachers can get the students’ results and progress of their classes, parents can get information of their children’s progress and result [8].

- **"HeyMath"
  "HeyMath" is a web-based e-learning system for primary and secondary schools. The aim of this system is to remove the fear of mathematics and make students learn mathematics in an interesting way [9]. However, it cannot provide the interface of presenting the descriptive statistics for students, their parents and teachers.

  In "HeyMath", lessons are created through suggestions from the University of Cambridge. With a highly mathematic editor; animated and interactive explanations, "HeyMath" can help students understand the concepts of mathematics [9].
"HeyMath" assesses students’ test in Grades 5 to 12 and follows various standards depend on different countries [9].

• "ACE-Learning System"

"ACE-Learning System" is a web-based mathematics e-learning system provides for secondary schools in Singapore. It provides an .asp application to present the descriptive statistics for e-learning system users every night. The aim of "ACE-Learning System" is to improve the mathematics learning in secondary schools. The features of this system are animated lessons, interactive laboratories, assessment questions and multi-criteria performance monitoring [10]. Student's data collection and analysis are used for evaluating program effectiveness, efficiency and has priority in ACE. Available data is average daily attendance, persistence to graduation, student retention, grade distributions and senior graduation informational surveys [10].

2.4 Statistical measures

Many measures are included in statistics field, such as mean, median, mode, standard deviation, minimum and maximum and so on. According to the requirements and specifications in the system, we used mean, mode, median and standard deviation in this project, the detail of these statistical measures are in following:

2.4.1 Mean

"In statistics, mean has two related meanings: arithmetic mean and population mean" [11]. The arithmetic mean is the average values in a data set, usually short called mean. The mean can be described as equation (1) by mathematical symbols.

\[
\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i
\]  

The population mean is the expect value in a data set [11]. In this project, we just used arithmetic mean to calculate the average grade in a class.

2.4.2 Median

The median is the middle value in the list of numbers [12]. To find the median, numbers have to be listed in numerical order firstly. If the number of data set is odd, the median is the value of (equation (2))th item term. If the number of data set is even, then the median is the value of (equation (3))th item term.

\[
\tilde{x} = \frac{n+1}{2} \text{ (n is odd)} 
\]  

(2)
\[ \bar{x} = \frac{\left( \frac{n}{2} + \frac{n+1}{2} \right)}{2} \quad \text{(n is even)} \quad (3) \]

### 2.4.3 Mode

The mode is the value that repeats most often in a set of numbers [13]. For example, in a data set \{1, 2, 2, 3, 4, 7, 9\}, the mode is the value of 2. The mode can be several values in a data set, but the mean and the median only can be one value.

### 2.4.4 Standard deviation

The standard deviation represents how much variation or dispersion from the mean. It is used to measure the spread of a set of data. A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data points are spread out over a large range of values [14].

For example, in the case where \(X\) takes random values from a finite data set \(x_1, x_2, \ldots, x_n\), with each value having the same probability, the standard deviation can be described as equation (4).

\[
\sigma = \sqrt{\frac{1}{n} \left[ (x_1 - \mu)^2 + (x_2 - \mu)^2 + \cdots + (x_n - \mu)^2 \right]} \quad \text{(Where } \mu = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i \text{ )} \quad (4)
\]
3 Methodology

3.1 Web-based e-learning systems

With increasing coverage of Internet in the world, people prefer to perform complex tasks through Internet. For example, people would like to transfer their accounts by e-bank. In addition, online business deals and online education are amazingly increasing in the last few years. Therefore, more and more web-based applications are developed currently.

Students will lose their interests in learning courses which they have a difficulty to understand. However, the web-based e-learning system can provide an interesting and easier way to learn, therefore rebuilding the students’ confidence.

“Ella Mathematics” is a web-based e-learning system, so the descriptive statistics module must be developed as a web-based application.

3.2 Solution stacks

To develop a web-based application, software engineers should choose a solution stack. Solution stack is a set of software that delivers all functional solutions in web designing. These programs include operating system, web server, database and scripting language. For instance, LAMP is a famous Linux-based solution stack.

3.2.1 Operating system

Operating system is a software environment which provides user interfaces for computer users. It manages the computer hardware and users’ program, as well as allows users’ programs to execute correctly on hardware. Operating system can allocate memory and resource whenever users required. At present, the mostly used operating systems are Microsoft Windows, Linux, and UNIX and so on.

In this project, the web-based application operates on the Microsoft Windows operating system as it easy to operate and can provide nice user interfaces.

3.2.2 Web server

A web server is a computer or hardware that delivers web pages to clients by HTTP (hypertext transfer protocol). Every web server has an IP (Internet protocol) address or domain name which allows users to access it. Web servers can support many server-side scripting languages, such as ASP, PHP, Perl, etc. When users send requests to the web server by typing a URL (Uniform Resource Locator) address in browsers, web server will send instructions to clients for
how to draw the web page (HTML, PHP). Figure 1 will present how the web server works.

![Web server components](image)

Figure 1 Web server works

Internet Information Services (IIS) is a web server which developed by the Microsoft Corporation; therefore, it only can run on Windows server operating systems. It contains a set of web services, such as FTP (File Transfer Protocol), HTTP (Hypertext Transfer Protocol), SMPT (Simple Mail Transfer Protocol), etc. IIS can support the script language of ASP, JAVA, VBscript and so on to generate web pages.

Apache web server is used in this project. Because Apache web server has a lot of advantages by comparing with other web servers.

- **Advanced features.** Apache is constantly updating their products to adapt the latest protocols in the Internet.
- **Easy to use.** Apache provides many configuration files that can guide web designers to configure and set it.
- **Low cost.** The API of Apache Server belongs to the Open Source Community.
- **Portability.** Apache provides the functionality of operating on any platforms [15].

### 3.2.3 Database

A database is a collection and storage of data. Database management system (DBMS) is software which provides the definition and manipulation of database. In an e-learning system, massive of data need to deal. These data include user data, exercise data, result data and so on.

SQL Server is a relational database management system which designed by Microsoft Corporation. Database engine is the core service of the SQL Server which responsible for data storing, processing, and security managing. The Oracle Database is an object-relational database management system which mostly used in big applications. PostgreSQL also is an object-relational database management, which supports the Structured Query Language (SQL), but adds its
own special extensions to create a special SQL server language. It is mostly used with Linux or UNIX operating systems.

In order to quickly retrieve data from database and save the cost, system engineers should select a proper database management system. In our case, MySQL is used to store system data.

The database management system of MySQL is based on relational model, in order to design an effective database that the designer needs a thoroughly understanding database model.

The advantages of MySQL are:
- Cost, MySQL is an open-source database management system, which can solve increasing costs that associated with storing data.
- Performance, MySQL shall be considered with increasing demand of products that can run on cross platform [16].

3.2.3.1 Problems related to database model
Several problems will discuss in this subsection, such as normalization, dimension tables that contain too many attributes and dimensions that occasionally change [17].
- Normalization
  Normalization is a technique for producing a set of suitable relations that support the data requirements of a company. These suitable set of relations might have the characteristics are:
  - The minimum number of attributes to support the data requirements for the enterprise;
  - Attributes with a close logical relationship are found in the same relation;
  - Minimal redundancies with each attribute which except the important attributes that form all or part of foreign keys.

The major benefits of normalization are:
- Administrators can access and maintain the database easily.
- Minimal usage of computer memory.

As normalization proceeds, the relations become progressively more restricted in format. To conduct a higher normalized form, completely understanding of lower normalized form is necessary.

- UNF(unnormalized form)
  A database table which contained one or more repeating groups.
- 1NF(normalized form)
  A relation that the intersection of each row and column contains only
one value. To convert UNF to 1NF, just identify the repeating groups and remove the repeating groups in an UNF relation.

- 2NF (normalized form)
  A relation which is based on 1NF and every non-primary-key attribute is fully functional dependent on the primary key. To convert 1NF to 2NF, just remove the partial functional dependency in a 1NF relation.

- 3NF (normalized form)
  A relation that is based on 2NF and no non-primary-key attribute is transitively dependent on the primary key. To convert 2NF to 3NF, just remove the transitive dependency in a 2NF relation.

Following 3NF, there are BCNF, 4NF, and 5NF and so on. By considering the complexity and feasibility of relations, we create a relational model of 3NF in this project.

- Dimension tables that contain too many attributes

If dimension tables contain so many attributes that can lead the poor performance and bad bandwidth, as the records increased to millions. In order to solve this problem, engineers need to separate out several groups of attributes from a dimension table and put them in a separate table which called minidimension table. A minidimension table contains a small group of attributes that are separated out from a larger dimension table.

To create a minidimension table can have following characteristics:

- The fields are rarely used as constraints in a query.
- The fields are frequently compared together. [17].

- Dimensions that occasionally change

Dimensions that occasionally change (which means that update infrequently) in a dimensional database, because of certain special reasons. For example, as regard to a company, company name and company address are rarely changed. Therefore, to make comparisons with historical and current, these changes must be handled when they do occur.

The IBM Corporation suggests three ways to handle changes that occur in a dimension:

- Change the value stored in the dimension column.
- Create a second dimension record with the new value and a generalized key.
- Add a new field in the dimension table for the affected attribute and rename the old attribute [17].
3.2.4 Scripting language
Scripting language is a kind of programming language which generally interpreted instead of compiled. There are several server-side and client-side scripting languages. For example, PHP and ASP are server-side scripting language and JavaScript is client-side scripting language. Scripting languages usually used to validate data and create user interfaces.

In this project, we choose the scripting language of PHP to get data from database and create graphical user interfaces.

3.2.4.1 PHP
PHP is a server-side scripting language which used to design web applications. Web designers can embed PHP codes into html pages wherever they need. Through the web server, PHP codes can be interpreted and generate an output to visitors [18].

PHP is an open source project, which means PHP programmer can have access to the source code and use, change and redistribute it without any charge [18]. PHP has much strength compare with other scripting language (such as Perl, JSP, ASP.NET, etc):
- Performance: because of using a single inexpensive server, PHP code can run fast.
- Database integration: which means PHP has a possibility to connect to a lot of database systems.
- Object-Oriented support, PHP has the features of inheritance, private and protected attributes and methods [18].

3.2.4.2 Object-oriented PHP
Object-Oriented Programming (OOP) is a form of programming which provides the features of inheritance, public, private and protest attributes and methods. PHP supports the features of Object-oriented just like C# and Java. Therefore, Object-oriented PHP can develop complex and reusable web applications [19].

It’s hard to define what an object independently, it’s easier to describe it together with another concept that of a class. A class is a general definition for a group of "thing". An object is an actual occurrence of a "thing". An object is also called an instance of a class [20]. For example, animal is a class that has feet and can run, dog is an instance of the class of animal, and cat is another instance of the same class.

PHP designers mostly used the way of including files and function to programming reusable code in PHP, but sometimes they find themselves doing the same thing over and over again. However, it seems not the same thing actually and can’t just include a file. Object-oriented PHP can solve the problems
of reusing codes by separating the application into different logical components. This is the reason why we choose object-oriented programming to develop an application in this project. We can create a PHP class like this (see Listing 1).

```php
1. class student
2. {
3.  var $student_id;
4.  var $student_name;
5.  function set_student_id($id){
6.    $this->student_id=$id;
7. }
8. }
```

Listing 1 Create a student class

### 3.3 Development model

When accept a project, the first thing is to choose a suitable development model which describes the process of development. From this project, we used waterfall (software development model) to create the whole system. To develop a system by waterfall model, firstly, developers need to completely know users’ requirements. Secondly, developers should get the specifications from users. And then, the developers are capable to design and implement this application which based on users’ requirements and specifications. Finally, test the system by requirements and specifications. Figure 2 is a waterfall software development model to show how to develop a web-based system.

![Waterfall software development model](image-url)
3.4 Development environment

To develop a web-based system, the significant process is to choose a better development environment that can help engineers to work more efficiently and consistently.

3.4.1 Wamp server
Wamp server is a web development environment which operates on windows operating system. With Wamp server, engineers can develop web-based applications with Apache web server, PHP scripting language and MySQL database. By PhpMyAdmin, engineers can manage their database conveniently and quickly [21].

In order to use Wamp server, engineers should create subdirectories which can put PHP or html files into them in “www” directory (The “www” directory will be automatically generated when users installed Wamp server, the path of it usually is c:\wamp\www). Engineers can open PHP or html files by typing URL: http://localhost in users’ browsers [21].

Because it has the advantages of easy to use and it is an open-source[21]. In this project, Wamp server was used to manage the Apache server and MySQL database, execute PHP files and so on.

3.4.2 Dream weaver
Dream weaver is a popular wildly used tool that can help designers to manage and design a web site. With Dream weaver that the engineer can create tables and forms, change style sheets, add JavaScript or behaviors in web pages. Dream weaver can only support to operate on windows and Mac so far. As the result of eases and efficient feature, designers can develop a website quickly and easily by Dream weaver, as well as efficiency to manage and update the website. In this project, Dream weaver was used to create a user interface.

3.4.3 Zend studio
The software Zend studio is an Integrated Development Environment (IDE) designed for PHP coding, but also it is a Java application which can run on any operating systems. Through this multi-function of an integrated development environment, the programmer can debug scripts through the scripts’ URL, requesting the Debug Server to load the script via HTTP. The Debugging Server connects to Zend Studio to use a socket, as well as using its multi-paneled interface to explore, editing files. It also has ability to monitor the output buffer, script output, debug trace, and track watch points [22]. Zend studio is used to program and debug PHP codes in this project.
3.5 User interface

In order to create a friendly user interface, a lot of web technologies and tools used in this project, such as html, CSS, JavaScript, Ajax, etc. The details of them will be introduced as following.

3.5.1 HTML

HTML (Hypertext Markup Language) is a language used to describe the web document. Through mark of the symbols that HTML can be shown every individual part of pages.

The page document itself is a kind of text file, and via adding "tags" into a text file that the page can tell the browser how to display the contents (such as: how to deal with word, how to arrange for pictures, how to display, etc.). The browser in order to read a page document successfully which based on the "tags" interpretation and show the marking of content. Meanwhile, to the writing of the wrong marks, the browser will not out of its mistake, and it will not stop the execution explain. The designer can only through the displayed result to analyze error reasons and areas [23].

HTML document production is not complex to create, and it has a powerful platform which supports to insert different data format files into the pages. This is one of the reasons why the WWW is so popular.

The main advantages are following:

- Simplicity: HTML uses a superset way to update its own version thus leading to more flexible and simple, for example, HTML5 is the newest version currently.
- Scalability: Due to the widely used of HTML language which brought some strengthen functions, such as increased the requirement of identifier, etc.
- Platform independence: HTML can be used into the broad range of platforms; this is another reason to demonstrate why the WWW is popular in the world [23].

In this project, html used to create basic web pages combing with CSS.

3.5.2 CSS

CSS is often used to design of the web page’s style. Through the establishment of sheet’s style that the designers can unity control of an HTML aspect of the display attributes [24].
Cascading style sheets not only can be more effectively aid designer to control web page's aspect, also can use to improve expand designated page elements' accurate position, appearance, and the ability to create special effects[24].

The latest version of the CSS was CSS3 which can truly separate with web page's performance and contents. Meanwhile, the CSS can also precise control of the position of the objects' layout in the web page and support almost all kinds of the font size style [24].

CSS used to implement the style of web pages in this project.

3.5.3 JavaScript
JavaScript is a client-side scripting language that runs on visitors' computer. It provides the functionality of validating forms and communicating with web servers [25]. It is used to create an interactive web site by combining with html and CSS.

The majority of JavaScript is used to validate data before data sent to the server. JavaScript generally used by web designers because of every browser supporting JavaScript perfectly. User event might be considered by using JavaScript, for example, user's key up or down. In this project, JavaScript used to create a dynamical user interface combing with html and CSS. Listing 2 demonstrates how to catch users' events by JavaScript.

```
1. <input id="hint" name="q" size="13"
    onkeyup="javascript:showHint(this.value)"
    onkeydown="javascript:if(event.keyCode==13){getdata();showchart(); return false;}"/>
```

Listing 2 Example JavaScript to catch the user's key

3.5.4 Ajax
Ajax (Asynchronous JavaScript and XML) is a set of web technologies that used to create interactive and dynamical web applications [26]. Web designers who want to make Internet applications smaller, faster and more user-friendly, AJAX should be considered. It is not a new web technology but including existing standard Internet technologies. Web designer who shall to use AJAX should have a basic understanding of the following:

- HTML/XHTML/CSS, for presentation.
- DOM (Document Object Model), for dynamically displaying.
- XMLHttpRequest, for asynchronous communication.
- JavaScript, for together with these technologies. [27]

Usually in many web pages (which do not use Ajax) must upload the whole page if the data has been updated. With Ajax can be updated data from a server
asynchronously. Ajax makes it possible to update web page without reloading the whole page. In our case, Ajax used to develop a dynamical user interface with JavaScript.

Different XMLHttpRequest will be sent to the web server since different browser with Ajax. Listing 3 presents a short example to show AJAX requests for different browsers.

```javascript
1. if (window.XMLHttpRequest)  
2. {// code for IE7+, Firefox, Chrome, Opera, Safari  
3. xmlhttp=new XMLHttpRequest();
4. }
5. else
6. {// code for IE6, IE5
7. xmlhttp=new ActiveXObject("Microsoft.XMLHTTP");
8. }
```

Listing 3 AJAX requests for different browsers.

3.5.5 jQuery

JQuery is a library of JavaScript functions. JQuery can run on any browsers as all browsers support JavaScript. The jQuery codes can be added to a web page with html tags [28]. The jQuery library contains the following features:

- HTML element selections
- HTML element manipulation
- CSS manipulation
- HTML event functions
- JavaScript effects and animations
- HTML DOM traversal and modification
- AJAX
- Utilities[29]

JQuery is free, open source software. JQuery provides the functionalities of traversing documents, selecting DOM elements, creating animations, catching users’ events and designing Ajax applications. JQuery also provides possibilities to add plugins on top of the JavaScript library [27]. In this project, jQuery used to load external php file by ‘div’ tags in html. A query example for loading external PHP file is presented in Listing 4.

```javascript
1. <script language="javascript" type="text/javascript"  
   src="jquery-1.7.2.min.js">  
2. functiongetData() {
3.  $('#chart').load('student.php');
```
3.5.6 Google chart PHP

Google Chart PHP which is a PHP Object wrapper for the Google Chart API [30], it can help anyone who needs to automatically build charts. It is a tool which can make PNG charts by sending a HTTP request to Google. To use this API, users should have knowledge of PHP programming.

The Google chart PHP library is an open-source and free to use wrapper for Google Chart API. Lots of type charts are defined in this library, such as, line chart, bar chart, pie chart and so on [31].

The significant difference between Google Chart library and other chart tools is that Google Chart PHP doesn't generate any images, but instead of generating an HTTP request to call Google Chart API. The followings are showing features of Google Chart PHP:

- Generation of the chart is blazing fast.
- It doesn’t require any additional PHP modules (like GD or imagemagick).
- Users can use the generated URL in an img HTML tag (<img>) and save bandwidth.
- Users also can fetch the PNG image and cache it locally [30].

Of course, there is a drawback in Google Chart PHP. Users rely on an external tool (Google Chart API) to generate charts; therefore users need to find other tools to create charts with highly secret data, because charts will be cached into Google’s servers for 2 weeks [30]. In our case, Google chart PHP used to make students’ learning progress dynamically. Listing 5 is example to create an overlapped bar chart which width is 300px and height is 200px.

```
1. <div id="chart"></div>
2. Listing 4 JQuery for loading external PHP file
3. 4. }
4. 5. </script>
3. 6. <div id="chart"></div>
3. Listing 4 JQuery for loading external PHP file
3. 3.5.6 Google chart PHP

```

```php
1. $barChart = new gOverlappedBarChart(300,200,'s');
2. $barChart->setVisibleAxes(array('x','y'));
3. $barChart->addDataSet($per_pass);
4. $barChart->addHiddenDataSet($per_pass);
5. $barChart->addValueMarkers('D','000000',3,0,3);
6. $barChart->addValueMarkers('D','ff00ff',4,0,3);
7. $barChart->setColors(array("009900", "22aacc","ff00ff","000000","ff00ff"));
8. ?></p>
9. <img style="display:block" src="<?php print $barChart->getUrl(); ?>"/>
10. Listing 5 Example of Google overlapped bar chart
11. <img style="display:block" src="<?php print $barChart->getUrl(); ?>"/>
```

Listing 5 Example of Google overlapped bar chart
4 Implementation and result

4.1 System PHP class structure

Four PHP classes are created to get different users’ information in this project. The class of user is the father class which class student, class parent and class teacher are all extends it, because students, parents and teachers are all users. Figure 3 shows the relationship between each class.

![Figure 3 PHP class structure](image)

4.2 Descriptive statistics

The results of statistics are getting from different users. There are three types of users in “Ella Mathematics”, students, parents and teachers.

4.2.1 Students

As regard to a specific student, he can only check his own result and has no power to see other’s result. Due to the login system was not inside this project that the system can not specify the user, but we should make sure the accuracy of statistics for each student. Therefore, the randomly statistics for student results are required.

For each student, he can get results from two areas (geometry and algebra) and six cities (Staden, Farmen...) so far. In order to allow students easy to check their result, we designed three colors to present task’s status and calculated the number of passed tasks for each city. In our case, green indicated pass, red indicated fail and black indicate unfinished. Figure 4 is an example to demonstrate the student’s result of geometry area.

![Figure 4 Student’s result of geometry area](image)
According to the status of student’s finished tasks, we created a progress bar which indicated the progress of doing tasks for each city. With this progress bar students can clearly get their learning progress, that student can easily find their weakness and be capable to improve it. Figure 5 is an example to demonstrate the student's learning progress in geometry area.

![Progress Bar Example](image)

**Figure 5** Student’s learning progress in geometry area

### 4.2.2 Parents

As regard to the specific parents, they can only check their own children’s result and average result. They have no power to see the others result.

For parents, they can get their children’s result from two areas (geometry and algebra) and six cities (Staden, Farmen...) so far. In order to allow parents easy to check their children’s result, we designed three colors to present task’s status, calculated the number of passed tasks and the average for each city. Figure 6 demonstrates the result that parents can see in geometry area.

![Result Table](image)

**Figure 6** The result that parents can see in geometry area

According to the status of children’s finished tasks, we created a progress bar which indicated the progress of doing tasks for each city. With these progress bars that parents can compare with the average and their children’s learning progress that parents can encourage or reward their children. Figure 7 is an example to demonstrate the children’s learning progress that parents can see in geometry area.
4.2.3 Teacher

With regard to a specific teacher, he can only check students’ result of his own class. However, in facts, a teacher might have to teach several classes at the same time. Therefore in this project, we designed a dropdown list (see Figure 8) which allows teachers to choose a class. Through this dropdown list that teachers can check students’ result class by class.

![Dropdown list which teachers can choose different class](image)

While teachers finished selecting a class, the system will provide three options (see Figure 9) which teachers can choose different mathematical areas and charts. In our case, there are geometry and algebra area that teachers can select, as well as charts for two areas.

![Three options provided to teachers](image)

In this system, we also provided a search function for teachers, meanwhile, a function of getting the hint for students’ name. If the teacher wants to search a specific student result, but they have not remembered this student’s name yet, in this case, a hint of student’s name is necessary. Figure 10 is an example to show the situation that when teachers typing character ‘d’ in the search box.
As regard to each teacher, after selecting students’ class and mathematical area, then the teacher can check students’ result for a specific class and area. In order to allow teachers easy to check students’ result and get information from each task, we designed three colors and numbers to present task’s status. In this case, green and 2 indicated pass, red and 1 indicated fail and black and 0 indicate unfinished. Furthermore, teachers can check the result of statistics by two aspects. Firstly, teachers can check each student’s grade, average grade (Avg by student), the dispersion of average grade (STD by student), the most frequent grade (Mode by student) and the middle value of grades (Median by student). Secondly, teachers can check each task’s status, average grade (Avg by task), the dispersion of average grade (STD by task), the most frequent grade (Mode by task) and the middle value of grades (Median by task). Through these statistics result, teachers can easily know about each student’ learning, as well as each task’s difficulty level. Therefore, teachers can improve their teaching. Figure 11 demonstrates the student’s result in the class of 001, the city of Staden and the area of geometry.

<table>
<thead>
<tr>
<th>Name</th>
<th>Upgift 1</th>
<th>Upgift 2</th>
<th>Upgift 3</th>
<th>Upgift 4</th>
<th>Upgift 5</th>
<th>Avg by student</th>
<th>STD by student</th>
<th>Mode by student</th>
<th>Median by student</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daniel</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1.2</td>
<td>1.1</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Anna</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1.2</td>
<td>1.1</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Merry</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1.0</td>
<td>1.0</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Brown</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.6</td>
<td>0.89</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Skyla</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Booth</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0.8</td>
<td>1.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Avg by upgift</td>
<td>1</td>
<td>1</td>
<td>0.67</td>
<td>0.83</td>
<td>1.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STD by upgift</td>
<td>1.1</td>
<td>1.1</td>
<td>1.03</td>
<td>0.88</td>
<td>0.82</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode by upgift</td>
<td>2.0</td>
<td>2.0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median by upgift</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0.5</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 11 The students’ result in the class of 001, the city of Staden and the area of geometry
For each student, according to the data from the table above, we drew the chart which represents the distribution of the grades, the average grade, the dispersion of the average grade, and so on. Through this chart, teachers can check each student’s study level easily and clearly. Figure 12 is an example to demonstrate Daniel’s statistics result.

Figure 12 Statistics Daniel’s grades

For each task, according to the data from the table above, we drew the chart which represents the distribution of grades, the average grade, the dispersion of the average grade, and so on. Through this chart, teachers can check each task’s difficulty level conveniently. Figure 13 demonstrates task1’s statistics result.

Figure 13 Statistics Uppgift1’s grades
According to the status of students’ finished tasks, we created progress bars which indicated the progress of students learning. With these progress bars teachers can clearly get the information of students’ learning progress from their class. Figure 14 demonstrates the student’s learning progress in the class of 001, the city of Staden and the area of geometry.

![Resultat i procent](image)

**Figure 14** The students’ learning progress in the class of 001, the city of Staden and the area of geometry

Since teachers selected a class, there is another option which is called ‘chart_all’. In this page, teachers can check the number of students’ finished and unfinished tasks, as well as the average number of passed tasks. Figure 15 is an example to demonstrate the number of students’ finished and unfinished tasks.

![Uppgifter information för alla studenter(Klass001)](image)

**Figure 15** The number of students’ finished and unfinished tasks

For a teacher, he can be gain information from this system and get to know students completed or passed cities. In this project, when a student finished one or more than one tasks in a city, then called this student completed this city. On the other side, when a student passed all of the tasks in a city, then called this student passed this city. Figure 16 demonstrates the number of students’ finished and unfinished cities.

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4.3 Proposed database model

Since the current database model is unnecessarily complex and difficulty that will be causing some problems in connection with different kinds of data (e.g. students and tasks).

The evaluation of the current database also brought up problems in the table structure considering normalization.

Another problem in current database model is large memory usage. In order to improve the current e-learning system, we proposed a new database model.

4.3.1 E-R model

E-R (entity-relationship) model is a conceptual model which abstract data from real things. Through E-R model, engineers can easily describe the system structure.

In this project, since the database model is so complex that we can’t use one E-R model diagram to represent the whole system structure, therefore we separate it to three parts to introduce.

- Users model
  For a user's aspect, he must have a specific user id, username and password. In addition, this user will have an email address, e-name, etc. According to the information of users, we designed four entities and three relations in user's model (see Figure 17).
    - Entity ella_users described the basic user information. Attribute id is a primary key which can identify a specific user; all non-primary-key attributes (username, hashed_password, etc) were fully functional dependent on the primary key.
    - Entity ella_types represented users' type. Attribute type_id is a primary key which identifies a user's type. Non-primary-key
attribute type was fully functional dependent on the primary key.

- Entity ella_plinks described the permalinks of users. Attribute plink_id is a primary key which identifies a user's permalink. Non-primary-key attribute permalink was fully functional dependent on the primary key.

- Entity ella_classes showed the classes for students. Attribute class_id is a primary key. Non-primary-key attribute class was fully functional dependent on the primary key.

- Relations 'have' represented the relationships among users, types, permalinks and classes. A user only has one user type, permalink or class, but many users might have the same user type, permalink or class. In these relations, there was no transitive functional dependency.

---

**Figure 17 User model diagram**

- **Tasks model**
  As regard to each task, it needs to belong to a specific city. In addition, each city needs to belong to the specific area. An area must have an area id and name, a city must have a city id and name, a task must have a task id and name. For each area, city and task, it might have a template and permalink.
  According to the task information, we designed five entities and eight relations in task model (see Figure 18).

  - Entity ella_areas represented the information of areas. Attribute area_id is a primary key which identifies a specific area. All non-primary key attributes (name, content and status) were fully functional dependent on the primary key.
Entity ella_cities represented the information of cities. Attribute city_id is a primary key which identifies a specific city. All non-primary key attributes (name, content and status) were fully functional dependent on the primary key.

Entity ella_tasks represented the information of tasks. Attribute task_id is a primary key which identifies a specific task. All non-primary key attributes (name, content and status) were fully functional dependent on the primary key.

Entity ella_templates represented the information of templates. Attribute template_id is a primary key which identifies a template. In this system, there are three templates available, area, city and task.

Entity ella_plinks represented the permalinks of areas, cities and tasks. Attribute plink_id is a primary key; attribute permalink is the name of each permalink.

Relation ‘area_city’ which is the relationship between areas and cities. For an area, it can have many cities, but a city only belongs to one area. There was no transitive functional dependency in this relation.

Relation ‘city_task’ which is the relationship between cities and tasks. For a city, it can have many tasks, but a task only belongs to one city. There was no transitive functional dependency in this relation.

Relations ‘have’ which is the relationship among areas, cities, tasks, templates and permalinks. An area, city and task only have a template and a permalink, but many areas, cities and tasks might have the same template or permalink. There was no transitive functional dependency in these relations.
When students finished tasks, there will have a relationship between students and tasks. For a student, he might pass or fail some tasks. According to the relationship between the students and task, we designed two entities and one relation in relations model (see Figure 19).

- Entity `ella_users` described the basic user information. Attribute `id` is a primary key which can identify a specific user. All non-primary-key attributes (username, hashed_password, etc) were fully functional dependent on the primary key.
- Entity `ella_tasks` represented the information of tasks. Attribute `task_id` is a primary key which identifies a specific task. All non-primary key attributes (name, content and status) were fully functional dependent on the primary key.
- Relation ‘ella_relations’ which is the relationship between students and tasks. For each student, he might do many tasks. For each task, it might be done by many students. In our case, students might pass or fail each task. There was no transitive functional dependency in this relation.
4.3.2 Data elements
According to the E-R model of 3NF designed before, we created sixteen tables to store all the system data, as well as defined data elements for each table. Data element is a set of precise definitions of data, such as data type, length, constraints and description. The following will introduce data elements table by table.

- **ella_users**
  In the table of ella_users, eight data elements were defined. The data element of user_id is a primary key and an id of user. Other data elements are non-primary-keys which described user's information. Table 1 presents data elements of ella_users.

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>user_id</td>
<td>int</td>
<td>11</td>
<td>primary key</td>
<td>user id</td>
</tr>
<tr>
<td>username</td>
<td>varchar</td>
<td>50</td>
<td>not null</td>
<td>user name</td>
</tr>
<tr>
<td>hashed_password</td>
<td>varchar</td>
<td>40</td>
<td>not null</td>
<td>password</td>
</tr>
<tr>
<td>salt</td>
<td>varchar</td>
<td>50</td>
<td>not null</td>
<td>salt with password</td>
</tr>
<tr>
<td>name</td>
<td>varchar</td>
<td>50</td>
<td>not null</td>
<td>name</td>
</tr>
<tr>
<td>ename</td>
<td>varchar</td>
<td>50</td>
<td>not null</td>
<td>e-name</td>
</tr>
<tr>
<td>email</td>
<td>varchar</td>
<td>50</td>
<td>not null</td>
<td>email</td>
</tr>
<tr>
<td>status</td>
<td>char</td>
<td>2</td>
<td>not null</td>
<td>user status</td>
</tr>
</tbody>
</table>

Table 1 The data elements of ella_users

- **ella_classes**
  In the table of ella_classes, two data elements were defined. The data element of class_id is a primary key and an id of class. The data element
of class is a non-primary-key which is the name of a class. Here are the
data elements of ella_classes (see Table 2).

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>class_id</td>
<td>smallint</td>
<td>11</td>
<td>primary key</td>
<td>class id</td>
</tr>
<tr>
<td>class</td>
<td>varchar</td>
<td>50</td>
<td>not null</td>
<td>class name</td>
</tr>
</tbody>
</table>

Table 2 The data elements of ella_classes

- **ella_user_class**
In the table of ella_user_class, three data elements were defined. The
data element of user_ id is a primary key and an id of user. The data
element of class_id is a foreign key and an id of class. The data element of
date which is the time that student attends in a class. Table 3 describes
the data elements of ella_user_class.

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>user_id</td>
<td>int</td>
<td>11</td>
<td>primary key</td>
<td>user id</td>
</tr>
<tr>
<td>class_id</td>
<td>smallint</td>
<td>11</td>
<td>foreign key</td>
<td>class id</td>
</tr>
<tr>
<td>date</td>
<td>timestamp</td>
<td></td>
<td>not null</td>
<td>The time to attend class</td>
</tr>
</tbody>
</table>

Table 3 The data elements of ella_user_class

- **ella_plinks**
In the table of ella_plinks, two data elements were defined. The data
element of plink_ id is a primary key and an id of user’s permalink. The
data element of permalink is the name of permalink. Here are the data
elements of ella_plinks (see Table 4).

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>plink_id</td>
<td>smallint</td>
<td>11</td>
<td>primary key</td>
<td>permalink id</td>
</tr>
<tr>
<td>permalink</td>
<td>varchar</td>
<td>50</td>
<td>not null</td>
<td>users’ permalink</td>
</tr>
</tbody>
</table>

Table 4 ella_plinks data elements

- **ella_user_plink**
In the table of ella_user_plink, two data elements were defined. The data
element of user_ id is a primary key and an id of user. The data element of
plink_id is a foreign key and an id of user’s permalink. Table 5 shows
the data elements of ella_user_plink.

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>user_id</td>
<td>int</td>
<td>11</td>
<td>primary key</td>
<td>user id</td>
</tr>
<tr>
<td>plink_id</td>
<td>smallint</td>
<td>11</td>
<td>foreign key</td>
<td>permalink.id</td>
</tr>
</tbody>
</table>

Table 5 The data elements of ella_user_plink
• ella_types
In the table of ella_types, two data elements were defined. The data
element of type_id is a primary key and an id of type. The data
element of type is a non-primary-key and the name of type. Here are the data
elements of ella_types (see Table 6).

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>type_id</td>
<td>smallint</td>
<td>11</td>
<td>primary key</td>
<td>type id</td>
</tr>
<tr>
<td>type</td>
<td>varchar</td>
<td>10</td>
<td>not null</td>
<td>type name</td>
</tr>
</tbody>
</table>

Table 6 ella_types data elements

• ella_user_type
In the table of ella_user_type, two data elements were defined. The data
element of user_id is a primary key. The data element of type_id is a
foreign key which is an id of type. Here are the data elements of
ella_user_type (see Table 7).

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>user_id</td>
<td>int</td>
<td>11</td>
<td>primary key</td>
<td>user id</td>
</tr>
<tr>
<td>type_id</td>
<td>smallint</td>
<td>11</td>
<td>foreign key</td>
<td>type id</td>
</tr>
</tbody>
</table>

Table 7 The data elements of ella_user_type

• ella_areas
In the table of ella_areas, seven data elements were defined. The data
element of area_id is a primary key which data type is big integer. Other
data elements are non-primary-key that described the information of an
area. Table 8 describes the data elements of ella_areas.

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>area_id</td>
<td>bigint</td>
<td>20</td>
<td>primary key</td>
<td>id of area</td>
</tr>
<tr>
<td>name</td>
<td>varchar</td>
<td>200</td>
<td>not null</td>
<td>name of area</td>
</tr>
<tr>
<td>content</td>
<td>longtext</td>
<td></td>
<td>not null</td>
<td>content in html</td>
</tr>
<tr>
<td>extra</td>
<td>text</td>
<td></td>
<td>not null</td>
<td>extra information</td>
</tr>
<tr>
<td>upload</td>
<td>text</td>
<td></td>
<td>not null</td>
<td>upload martial</td>
</tr>
<tr>
<td>status</td>
<td>char</td>
<td>2</td>
<td>not null</td>
<td>status</td>
</tr>
<tr>
<td>date</td>
<td>timestamp</td>
<td></td>
<td>not null</td>
<td>current date</td>
</tr>
</tbody>
</table>

Table 8 The data elements of ella_areas

• ella_cities
In the table of ella_cities, seven data elements were defined. The data
element of city_id is primary key which data type is big integer. Other
data elements are non-primary-key that presented the information of a
city. Table 9 presents the data elements of ella_cities.
In the table of ella_tasks, seven data elements were defined. The data element of task_id is a primary key which type is big integer. Other data elements are non-primary-key that described the information of task. Here are the data elements of ella_tasks (see Table 10).

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>task_id</td>
<td>bigint</td>
<td>20</td>
<td>primary key</td>
<td>id of task</td>
</tr>
<tr>
<td>name</td>
<td>varchar</td>
<td>200</td>
<td>not null</td>
<td>name of task</td>
</tr>
<tr>
<td>content</td>
<td>longtext</td>
<td></td>
<td>not null</td>
<td>content in html</td>
</tr>
<tr>
<td>extra</td>
<td>text</td>
<td></td>
<td>not null</td>
<td>extra information</td>
</tr>
<tr>
<td>upload</td>
<td>text</td>
<td></td>
<td>not null</td>
<td>upload martial</td>
</tr>
<tr>
<td>status</td>
<td>char</td>
<td>2</td>
<td>not null</td>
<td>status</td>
</tr>
<tr>
<td>date</td>
<td>timestamp</td>
<td></td>
<td>not null</td>
<td>current date</td>
</tr>
</tbody>
</table>

Table 10 The data elements of ella_tasks

In the table of ella_area_city, two data elements were defined. The data element of city_id is a primary key and an id of area. The data element of area_id is a foreign key and an id of city. Here are the data elements of ella_area_city (see Table 11).

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>area_id</td>
<td>int</td>
<td>11</td>
<td>foreign key</td>
<td>area id</td>
</tr>
<tr>
<td>city_id</td>
<td>int</td>
<td>11</td>
<td>primary key</td>
<td>city id</td>
</tr>
</tbody>
</table>

Table 11 The data elements of ella_area_city

In the table of ella_city_task, two data elements were defined. The data element of task_id is a primary key which data type is integer. The data
element of city_id is a foreign key and an id of task. Table 12 shows the
data elements of ella_city_task.

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>city_id</td>
<td>int</td>
<td>11</td>
<td>foreign key</td>
<td>city id</td>
</tr>
<tr>
<td>task_id</td>
<td>int</td>
<td>11</td>
<td>primary key</td>
<td>task id</td>
</tr>
</tbody>
</table>

Table 12 The data elements of ella_city_task

- ella_templates
  In the table of ella_templates, two data elements were defined. The data
element of temp_id is a primary key which type is integer. The data
element of template is a name of the template. Table 13 describes the
data elements of ella_templates.

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>temp_id</td>
<td>int</td>
<td>11</td>
<td>primary key</td>
<td>template id</td>
</tr>
<tr>
<td>template</td>
<td>varchar</td>
<td>30</td>
<td>not null</td>
<td>template name</td>
</tr>
</tbody>
</table>

Table 13 The data elements of ella_templates

- ella_task_template
  In the table of ella_task_template, two data elements were defined. The data
element of id is a primary key which includes area id, city id and
task id. The data element of temp_id is a foreign key which provides the
id of template for a specific area, city or task. Table 14 shows the data
elements of ella_task_template.

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>temp_id</td>
<td>int</td>
<td>11</td>
<td>foreign key</td>
<td>template id</td>
</tr>
<tr>
<td>id</td>
<td>bigint</td>
<td>20</td>
<td>primary key</td>
<td>area, city or task id</td>
</tr>
</tbody>
</table>

Table 14 The data elements of ella_task_template

- ella_task_plink
  In the table of ella_task_plink, two data elements were defined. The data
element of id is a primary key which includes area id, city id and task id. The data
element of plink_id is a foreign key which provides the id of permalink for a specific area, city or task. Table 15 presents the data
elements of ella_plink.

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>plink_id</td>
<td>int</td>
<td>11</td>
<td>foreign key</td>
<td>permalink id</td>
</tr>
<tr>
<td>id</td>
<td>bigint</td>
<td>20</td>
<td>primary key</td>
<td>area, city or task id</td>
</tr>
</tbody>
</table>

Table 15 The data elements of ella_plink

- ella_relations
  In the table of ella_relations, five data elements were defined. The data
element of id is primary key which type is big integer. The data elements
of user_id and task_id are foreign keys. The data element of complete to describe a student completes a specific task or not. The data element of pass to show a student passes a specific task or not. Table 16 presents the data elements of ella_relations.

<table>
<thead>
<tr>
<th>name</th>
<th>data type</th>
<th>length</th>
<th>constraints</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>id</td>
<td>bigint</td>
<td>20</td>
<td>primary key</td>
<td>id for each relation</td>
</tr>
<tr>
<td>user_id</td>
<td>int</td>
<td>11</td>
<td>foreign key</td>
<td>user id</td>
</tr>
<tr>
<td>task_id</td>
<td>int</td>
<td>11</td>
<td>foreign key</td>
<td>task id</td>
</tr>
<tr>
<td>complete</td>
<td>char</td>
<td>2</td>
<td>not null</td>
<td>whether to complete</td>
</tr>
<tr>
<td>pass</td>
<td>char</td>
<td>2</td>
<td>not null</td>
<td>whether to pass</td>
</tr>
</tbody>
</table>

Table 16 The data elements of ella_relations

4.4 Compare with current model and proposed

Since the current database had the problems of normalization, therefore we proposed a new database model for the company. However, why the company will accept the new database model? A comparison with current and proposed database model is needed. This comparison will conduct from data redundancy, memory usage and speed three aspects.

4.4.1 Data Redundancy

There are plenty of unnecessary redundant data in the current database model. However, in our database model, we avoid this redundancy by using the third normal form. The details of comparison are in following:

- **Current model**
  In the current database model, the table of ella_users has much redundant data. Such as repeated classes, permalinks and types (See Figure 20).

<table>
<thead>
<tr>
<th>id</th>
<th>class</th>
<th>username</th>
<th>permalink</th>
<th>hashed_password</th>
<th>salt</th>
<th>name</th>
<th>username</th>
<th>email</th>
<th>type</th>
<th>date</th>
<th>status</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>101</td>
<td>Daniel</td>
<td>student</td>
<td>student</td>
<td></td>
<td></td>
<td></td>
<td>Daniel</td>
<td></td>
<td>2013-04-15 19:00:00</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>101</td>
<td>Anna</td>
<td>student</td>
<td>student</td>
<td></td>
<td></td>
<td></td>
<td>Anna</td>
<td><a href="mailto:Anna1@gmail.com">Anna1@gmail.com</a></td>
<td>2013-03-14 10:00:00</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>102</td>
<td>Roland</td>
<td>student</td>
<td>student</td>
<td></td>
<td></td>
<td></td>
<td>Roland</td>
<td><a href="mailto:Roland02@gmail.com">Roland02@gmail.com</a></td>
<td>2013-03-30 10:00:00</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>102</td>
<td>Andrew</td>
<td>student</td>
<td>student</td>
<td></td>
<td></td>
<td></td>
<td>Andrew</td>
<td><a href="mailto:Andrew19@gmail.com">Andrew19@gmail.com</a></td>
<td>2013-03-13 15:13:13</td>
<td></td>
</tr>
</tbody>
</table>

Figure 20 The table of ella_users in current model
• Proposed model

In proposed model, we identified and removed the redundant data by using the third normal form. In our case, ella_users, ella_classes, ella_types, ella_plinks, ella_user_class, ella_user_type, ella_user_plink seven tables are describing users’ information. There is no any redundant data in our database model (See Figure 21).

![Figure 21 The tables in proposed model](image)

<table>
<thead>
<tr>
<th>user_id</th>
<th>username</th>
<th>hashed_password</th>
<th>salt</th>
<th>name</th>
<th>email</th>
<th>status</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Daniel</td>
<td>...</td>
<td>Daniel</td>
<td>Daniel</td>
<td>...</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Anna</td>
<td>...</td>
<td>Anna</td>
<td>Anna</td>
<td>...</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Roland</td>
<td>...</td>
<td>Roland</td>
<td>Roland</td>
<td>...</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Andrew</td>
<td>...</td>
<td>Andrew</td>
<td>Andrew</td>
<td>...</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>user_id</th>
<th>class_id</th>
<th>date</th>
<th>user_id</th>
<th>type_id</th>
<th>user_id</th>
<th>plink_id</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1001</td>
<td>2012-04-04</td>
<td>3</td>
<td>2001</td>
<td>2</td>
<td>3001</td>
</tr>
<tr>
<td>3</td>
<td>1002</td>
<td>2012-04-14</td>
<td>3</td>
<td>2001</td>
<td>3</td>
<td>3001</td>
</tr>
<tr>
<td>4</td>
<td>1001</td>
<td>2012-03-05</td>
<td>4</td>
<td>2001</td>
<td>4</td>
<td>3001</td>
</tr>
</tbody>
</table>

4.4.2 User data storage

In order to solve the problem of normalization in the current database model, we changed the number of tables and table structure in the proposed database model, the user data storage also changed with numbers of users were created.

In this project, we calculated the data storage by the tool of Micro office excel. In this case, in order to compare with the user data storage of two models accurately, we used the same data. According to the result, when the number of users is increasing, the proposed model is more save the data storage (see Figure 22). For example, when the number of user is 500, the current model will use 93500byte (91.31KB) to store users’ data. However, the proposed model just use
84596 byte (82.61KB) to store the same data, therefore, the proposed model can save 8.7KB.

Therefore, in the aspect of user data storage, when the number of user is increasing, the performance of proposed database model is better.

### 4.4.3 Speed of retrieving data

Comparing two database models, the speed of retrieving data is a significant aspect. Developers can improve their system by improving the speed of retrieving data from database. We will do this comparison by two examples.

- **Select a specific student completed tasks**

  In the current database, in order to get all completed tasks for a specific student. Firstly, select task strings by database manipulate language (DML), after programmers need to split each task from task strings by PHP code. Because the speed of executing codes is so quickly, thus we used microseconds to measure the time of retrieving data (see Listing 6). The result indicates that it will use 0.00063 microseconds averagely to select a specific student completed tasks by the current database model. Here is an example to measure the time to select Daniel’s completed tasks.
1. $start=microtime(true);
2. $count = 0;
3. while($count++<1000)
4. {
5. $query="select * from ella_relations where user_id=(select id from ella_users where username='Daniel')";
6. $result= mysql_query($query);
7. while ($row= mysql_fetch_assoc($result))
8. {
9. $explodelt=explode(',',$row['relation']); //split completed tasks
10. $task_all[$row['type']]=$explodelt;
11. }
12. $task_complete=$task_all['uppgif_comp'];
13. }
14. $current=microtime(true);
15. $diff=round(((current-$start)/1000),5);

Listing 6 Measure the time to get Daniel’s completed tasks in current database

However, in our database model, to get all completed tasks for a specific student. We just select task by data manipulate language (see Listing 7). The result indicates that it will use 0.00061 microseconds averagely to select a specific student completed tasks, therefore, the proposed model will quicker than the current model.

1.$start=microtime(true);
2. $count=0;
3.while($count++<1000)
4. {
5. $query="select task_id from ella_relations where user_id=(select user_id from ella_users where username='Daniel') and complete='1' ";
6. $result= mysql_query($query);
7. while($row= mysql_fetch_assoc($result))
8. {
9. $task[]=$row['task_id'];
10. }
11. }
12. $current=microtime(true);
13. $diff=round(((current-$start)/1000),5);

Listing 7 Measure the time to get Daniel’s completed tasks in proposed database
Select the area that a specific task (which task_id is 16) belonged

In order to get a specific task's area from the current database model, firstly get this task's city by database manipulate language, then can get this task's area by database manipulate language (see Listing 8). The result indicates that it will use 0.00067 microseconds to get a specific task's area.

```php
1.$start=microtime(true);
2.$query="select page_parent from ella_pages where id='16'";
3.$result= mysql_query($query);
4.$count=0;
5.while($count++<1000)
6.{
7.while ($row= mysql_fetch_assoc($result))
8. {
9.$city_id=$row['page_parent'];
10.}
11.$query1="select page_parent from ella_pages where id='$city_id'";
12.$result1= mysql_query($query1);
13.while($row=mysql_fetch_assoc($result1))
14.{
15.$page_id=$row['page_parent'];
16.}
17.}
18.$current=microtime(true);
19.$diff=round(((($current-$start)/1000),5);
```

Listing 8 Measure the time to get a task's area in current database

However, to get a task’s area from proposed database, we just select area id by data manipulate language once (see Listing 9). The result indicates that it will use 0.00037 microseconds to get a specific task’s area; therefore, the proposed model will quicker than the current model.

```php
1.$start=microtime(true);
2.$count=0;
3.while($count++<1000)
4.{
5.$query="select area_id from ella_area_city where city_id=(select city_id from ella_city_task where task_id='16')";
6.$result= mysql_query($query);
7.while($row= mysql_fetch_assoc($result))
8.{
9.$area_id=$row['area_id'];
```
Listing 9 Measure the time to get a task's area in proposed database

```php
10.}
11.}
12.$current=microtime(true);
13.$diff=round(((current-$start)/1000),5);
```
5 Conclusion and discussion

From this project, we learned how to design and implement a web-based e-learning system, as well as statistics students’ grades for the system.

To design and implement a software system, the significant process is to choose a software model and better development environments. Because of the software model along with the whole procedure of developing a software system, and the better development environment can help developers work more efficiently.

5.1 Discussion

We use Google chart to draw chart because it very simple, convenient and free, but Google chart also has a drawback, the data used to draw chart will be stored in Google server two weeks, if the data is important and security, choose Google chart is not a good idea.

Object-Oriented programming plays an important role in this project. In the project, Object-Oriented used to create PHP classes. With Object-Oriented programming, the feature of inheriting can help programmers solve the problems of reusing codes in PHP programming, as well as easy to modify and maintain codes.

5.2 Conclusion

With the finished project statistics in “Ella Mathematics”, the project had completed the specified goals.

- Evaluate the current system

After evaluating the current system architecture and analyzing the database from the company, we found problems which considered normalization in the current database. Therefore, we promoted the database and design our own database (proposed database in the result section).

- Compare to existing system architecture

Through comparing the existing system, we have promoted the system architecture in some features, such as interface and assessment questions.
• E-learning system and statistics

We have created a website and designed three parts of descriptive statistics for students, parents and teachers. The site can display the statistics results correctly.

• Descriptive statistics can display correctly with different system and browsers

We have tested the statistics results can display in Windows, Linux, iOS and android system correctly, and in different browsers (Firefox, IE, Opera, etc).

5.3 Future work

This project work is statistics in "Ella Mathematics", but the functionality of user login is not inside this project. Because the result of students statistics displayed on the web page is random, the system cannot specify a user’s result to display. For “Ella Mathematics” itself, it must have register and login function. In addition, records of registering and login should be stored in database. With different permissions, students only can check their own results; parents only can check the result which related their children and teachers only can check their own class results.

Internationalization of "Ella Mathematics" is another point, in this project, the language is Swedish. In the future, the software system may have different language versions, that the people who in different countries can choose their own language to learn mathematics.

These two tasks are not involved in this project, in the future, these works can be continued to complete.
Reference


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