Department of Computer Science
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Final Year Project
Interactive Web Content for STEM
Individual Final Report

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Abstract

STEM Education is promoted worldwide to equip students with the capability to get ready for the challenge in the world with rapid economic, scientific and technological developments. STEM Education in Hong Kong is mainly promoted in the curriculum context. However, the success of STEM Education cannot be achieved in schools alone and STEM development in Hong Kong is falling behind.

A web tool is developed as the Final Year Project for enhancing teenager’s knowledge and motivation of STEM with interactive content related to science and mathematics. The web application is deployed on the Amazon Web Services (AWS) and user data will be stored in the AWS relational database.

This application can allow users to study STEM contents on the internet. STEM education no longer limited in schools. It is hoped that the application can help students to study STEM knowledge in an efficient way, as well as promoting STEM education in Hong Kong.
Acknowledgement

I would like to express my greatest appreciation and gratitude to Dr Vincent Lau for the constant supervision and guidance of my FYP project. He has been simulating suggestion and providing information regarding the project.
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Table 2  Working Schedule

Abbreviations

API     Application programming interface
MVC    Model-view-controller
AWS    Amazon Web Service
STEM   Science, Technology, Engineering, Mathematics
1. Introduction

1.1 Background

STEM is a short-term for Science, Technology, Engineering and Mathematics. In the age of information, most fields of study and application such as engineering, accounting, medicine play an important role in modern economies, they are indispensable to technology-driven society and they rely on a strong STEM background. For instance, STEM-related jobs are continuously growing worldwide. According to the report of U.S. Economics and Statistics Administration, STEM-related jobs grew 24.4 per cent over the last decade, and STEM-related jobs are predicted to grow by 8.9 per cent from 2014 to 2024 [2]. The current STEM workers are not adequate for the growing demand in the society. Therefore, a solid STEM education is essential to sustainable economic growth and competitive advantages [1].

Apart from society development, being proficient in STEM is beneficial to personal life. As STEM disciplines encourage creativity, critical thinking and problem-solving, it helps teenagers to develop a logical mindset. Students with a logical mindset are able to solve complex questions and develop solutions for real-world problems in different disciplines. Besides, most of the STET-related jobs are well-paid and secured. According to the report of U.S. Economics and Statistics Administration, the salaries of STEM job is 29% higher than the non-STEM job and the unemployment rate is lower than non-STEM job [2]. Therefore, being proficient in STEM increase personal capability and competence in different industries, and it is beneficial for pursuing a better job in the future.
1.2 Motivation
First, the promotion of STEM education in Hong Kong is mainly archived in schools alone, STEM education is rarely promoted outside of schools. Second, there are many STEM resources on the internet, but most of them are designed as teaching tools for teacher only. As a result, there are few STEM contents for students to learn on the internet. Last but not least, most of the STEM resources are lack of interactive contents. The ways that students study the STEM resources are simply reading and watching, the lack of interactive contents of STEM resources has lower efficiency of learning STEM and makes STEM contents look boring.

1.3 Objective
This project aims to create an online learning platform with interesting and interactive content related to STEM to assist high school students in learning STEM and promote STEM education in Hong Kong. The contents are designed to enhance high school student’s knowledge and motivation of STEM. To achieve this, the website will provide a user-friendly interface and give a real-time response to users to improve the efficiency of learning STEM.

The goal of this project is to create a website which has the following features:

1. Serving as an online learning platform for STEM Education.
2. Providing Interactive Contents for users to study STEM knowledge efficiently.
3. Gather User Behavior Data for STEM Education analysis.
2. Methodology

2.1 Overview

The project consists of a single page web application and a web framework. The main platform of development of the web application is Angular and the platform of development of the web framework is ASP.NET Core. Some external services for web hosting and web tracking are used in this project. This section will discuss the methodology of implementation in details.

2.2 Development Environment

Angular is a web development platform. It is popularly used for single page web application that live on the web, mobile, or the desktop. Typescript is used to write scripts in Angular.

ASP.NET Core is a web framework. It is used to support the development of web applications including web services, web resources, and web APIs. It provides tools such as MVC pattern and Entity Framework Core to speed up development time.
2.3 System Architecture

The system architecture consists of Web Interface, Web Server, Web application and a Database. Users can interact with the web interface and send request to the web server for different actions. Users communicate with the web application by HTTP protocol. The web application is responsible for processing user requests, sending reply to user, handling the storage and retrieval of user data in the connected database.
2.4 Web Interface

The web interface is responsible for the delivery of information to the user. The web interface is developed as a single page application which has better interactivity and responsiveness than Traditional Page Application. Single page application provides end users a more comfortable experience such as no page reloading. Most user interactions can be handled without reaching the server which means users can instantly receive the response from the application without waiting for the server.

However, the performance of the web application will be heavily relying on the strength of user device. To avoid the that, the complexity of the interactive content is designed as low as possible.

A user-friendly and attractive looking web Interface is essential for a successful web application. Bootstrap is utilized to make the web interface more attractive and convenient.

![Bootstrap](image)

*Figure 4. Bootstrap*

2.5 Server-Side Web Application

The server-side application is a web application programming interface (API) written in C# connected to a Microsoft SQL server relational database. It is responsible for supporting the web interface with storage and retrieval services. The web API is developed in MVC pattern.
2.6 Web Hosting Service

The web application needs to be accessible via the World Wide Web. To achieve that, the application is developed with cloud platform Amazon Web Service. Amazon Web Service S3 is used for hosting the web interface, it allows user to retrieve the web interface without server implementation. The Web API is hosting on Amazon Web Service Elastic Beanstalk for providing server-side services and the Microsoft SQL Server is created with Amazon Web Service Relational Database Service for data storage. Also, cloud computing does not require hardware configuration and maintenance which can speed up the development.

![Amazon S3, AWS Elastic Beanstalk, AWS RDS](image)

*Figure 5. AWS S3, AWS Elastic Beanstalk, AWS RDS*

2.7 Interactive Content

This section will describe the methodology of interactive content provided by this application and the interaction between users and the application.

2.7.1 Simulation

The application provides simple simulations of each topic to help users to study STEM knowledge. Users can try different input in the simulation section, the web application will automatically calculate the output and give a real-time response to the user. Users can play with the simulations and study STEM topics without acquired any related knowledge.
2.7.2 Game

The application provides games for users to test their understanding of STEM topics. After the user read all the materials in the topic, a game challenge is offered to the User. Moreover, the game result will be stored in the database for analytical use.

2.7.3 Animation

Animation are designed to give visual information of STEM topics. It can help users to understand topics like cryptography which can be illustrated with animation. The animation is written by using CSS3 and Angular Animation.

![CSS3](image)

Figure 6. CSS3

2.7.4 Video

Video are recommended at the end of each topic for users to study the related topic of STEM knowledge. The video provided in the application is embed YouTube video from YouTube.com which is selected for teenagers to study STEM knowledge.

2.8 Tracking User Browsing Time

For STEM studying analysis, the application needs to keep tracking of User behavior in the web interface. To achieve that, Google Analytics is used for collecting user data and generating report for the view of the web application and the view of the individual page to analyze teenager STEM learning behavior.

![Google Analytics](image)

Figure 7. Google Analytics
3. Result and Deliverable

3.1 Overview

A functional web interface and web API have been implemented and tested. More Contents and new features have been added to the application as the progress of the project proceed. This Section will describe a detail review of the application.

3.2 Web Interface

This is the major part of this project as the web application heavily depends on the design of the interactive contents in the web interface. The web interface has been set up on AWS S3 Services and it can be accessed by the public at http://iwcs-stem.s3website-ap-southeast-1.amazonaws.com.

![Figure 8. Front Page](image-url)
3.3 Web API

The Web API is responsible for supporting the web interface. It accepts requests for posting game score and retrieving game score. After user finished a game, the API will process the request from the web interface and store the data to the connected database and the data can be retrieve by requesting the API. The web API has been deployed on AWS Elastic Beanstalk Services.

Moreover, the Web API also provide user management services such as register and authentication. At the current stage of the project, the user management services are not required for the web interface. It can be utilized in the future stage of the development.

Figure 9. Web API Structure

Figure 10. AWS Elastic Beanstalk Server
3.4 Relational Database

The Database is responsible for the storage of the game data in the user interface. Currently, the database will store the data of the Caesar Cipher Game, Fourier Series Game and the Fourier Transform Game.

Structure for Score Table:

<table>
<thead>
<tr>
<th>Id</th>
<th>Unique identifier of a record.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>The datetime when the game finish</td>
</tr>
<tr>
<td>Score</td>
<td>The game score after the game finish</td>
</tr>
</tbody>
</table>

*Table 1. Structure of the score table*

Moreover, the tables for user management services has been established. Although it is not applicable for the current stage of the project, it can be utilized in the future stage of the development when user management services are required.
3.5 Fourier Series Simulator

This is the user interface of the Fourier Series Simulator. An animated graph of the Fourier Series is shown in the top left corner and the current graph information is shown in the top right. The bottom part of the simulator is for user to interact with the simulator.

![Fourier Series Simulator](image)

**Figure 12. UI of the Fourier Series Simulator**

First, user can select different wave at the beginning, there are 4 default waves provided to user. User can also create his own wave by selecting custom wave. Second, user can alter the number of wave or a specific wave in the series. After altering the series, simulator response immediately and user can observe the series.

![Fourier Series Simulator](image)

**Figure 13. Features of Fourier Series Simulator**
3.6 Fourier Series Game

When user visit the Fourier Series game page, the game UI will be shown. The Fourier Series game is a Q&A game. User need to answer the correct function which match the animated wave shown at the top.

![Figure 14. UI of Fourier Series Game](image)

After user select a function, the corresponding function will be shown on the graph to help user to verify the function. (Figure 1). Users will gain score if they answer the question correctly and lose score if they give the wrong answer. At the end of the game, the score will be sent to the server and stored in the database.

![Figure 15. Fourier Series Game (after selection)](image)
3.7 Fourier Transform Simulator

There are multiple Simulators in the topic of Fourier Transform, we discuss one of the simulators. In the Fourier Transform Simulator, the time domain graph and frequency domain graph are shown on the top. User can interact the simulator by using the buttons and scrollers at the bottom.

**Figure 16. UI of Fourier Transform Simulator**

First, User can add or remove wave from the simulator. To avoid performance issue caused by heavy calculation, the maximum number of waves in the simulator is 4. Also, user can alter a specific wave and the simulator will response immediately to simulate Fourier Transform for user to observe the result.

**Figure 17. Feature of Fourier Transform Simulator**
3.8 Fourier Transform Game

When user visit the Fourier Series game page, the game UI will be shown. In this game, a time function is shown on the left and a frequency function of that wave is shown on the right. Users need to create the same time function by observing the frequency function.

![Figure 18. UI of Fourier Transform Game](image)

User can alter the waves they need to create the time function by adding or removing the waves or alter the value of specific wave. After user alter the waves, the game will response the graph they created which used to help user to verify the answer. At the end of the game, the score will be sent to the sever and stored in the database.

![Figure 19. Fourier Transform Game (demo)](image)
3.9 Cryptography Game

A game is designed related to Caesar Cipher for Cryptography. This game is in Q&A format. Users are required to decrypt or encrypt the message to answer the correct question.

![Figure 20. UI of Caesar Cipher Game](image)

User can drag the answer to the answering place. If User answer the question correctly, user will gain score and a Treasure will be shown up. User can drag the treasure to item slots and keep it for later stage of the games. If User give the wrong answer, the answer will become red to indicate a wrong answer and user will lose mark. At the End of the game, the score will be sent to the server and stored in the database.

![Figure 21. Caesar Cipher Game(demo)](image)
3.10 Animation

Animation is delivered in the Cryptography topic. It gives a visual information for user to learn how different method works in cryptography. The animations illustrate the process of sending a message with No protection, Hashing, Symmetric Key and Asymmetric Key.

![Asymmetric Key Animation](image)

**Figure 22. Asymmetric Key Animation**

3.11 Video

Embed YouTube video shared from YouTube are recommended in the web application. Each topic has at least one embed video that I found useful and highly recommended for watching.

*Appendix: A Visual Introduction To Fourier Transform*

An excellent video to introduce the fourier transform.

![Fourier Visualized](image)

**Figure 23. Video of Fourier Transform**
3.12 Google Analytics

Google Analytics is used in the web interface to track user behavior and send the data back to the Google API. Google Analytics will generate real time report and daily behavior report of page viewing. It will record page view of each individual page in the web application. The data can be used for studying teenagers STEM learning behavior in the future.

Figure 24. Google Analytics Behavior Report
4. Future Works

4.1 Overview
At the current stage, the web application provides sufficient feature to achieve the objectives of this project. But there are still improvements can be made for providing better STEM content and more user-friendly features to improve the efficiency of STEM Education.

4.2 Responsive web design
Currently, the web interface does not support responsive web design due to the plotting components and animations in the application needed to be fixed size. In the current stage, the web interface is fixed with a minimum width to support different device, but a responsive web design will make the web application look better on all device. However, the complexity of developing plotting components for complex STEM topics such as Fourier Transform will be very challenging which the redesign of components will be an issue in developing responsive web application.

Peer learning
Peering learning is a way to enhance the feature of the application to reach the objectives. An online community can be made that users can post STEM related question, share STEM knowledge and solve STEM problems with their peers. For example, a comment section that allow users to leave comments and questions in the application. The comments and question will be stored in the database and retrieved by other users. This comment section can provide a peer learning experience to users to improve the efficiency of learning.
4.3 STEM Topic

As there are countless of topics STEM related topics, the range and depth of STEM information is very huge. This web application has just introduced some popular STEM-related topics and explained the surface knowledge. There are two direction to improve the web application. The first direction is to introduce more STEM related topics in the web application, this allow user to know more different STEM knowledge and discover their favorite STEM topics. Another direction is to provide a more comprehensive and interactive contents to user. This allow user to be acquainted with specific STEM related topics. Both directions can improve the quality of the web application to reach the objective in the project.

4.4 User Management Service

As mentioned in section 3.3 and 3.4, the basis of user management services has been developed but not applicable for the current stage of the application. The advantage of using user management services is that it is easier to keep track of individual learning progress which is suitable for Education in School. There is already similar application such as English Builder introduced to many Schools. This application can use the same approach to be introduced to schools for STEM learning purpose only.
5. Difficulty and Limitation

5.1 Difficulty encountered

The biggest challenge in the project is designing interactive content. As there are countless STEM-related topics, it is infeasible to design all of them. Moreover, the content must be inspiring and interactive in order to increase the interest and motivation of STEM. The proposed method for designing content is to select the most popular and common STEM topics as the content. Also, the application will collect feedback from users for designing better interactive content.

5.2 Limitation of the project

In the current stage, the web application only supports English. As the current Education curriculum context in Hong Kong are teaching in English or Chinese, students who are not good at English may not understand the STEM content of the application. It is best to use English because it is the most common language in the world, and it is more effective in searching. Multiple languages will be focused in the future scope if it is necessary.

Another limitation is from Amazon Web Service, the current services used in this application only allow 20000 Get Requests per month which means only 20000 views per month. The application will be out of service if the website is frequently accessed.
## 6. Working Schedule

<table>
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<th>Task</th>
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<td>Research on technology</td>
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<td>Project plan and website</td>
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<tr>
<td>October</td>
<td>Establish Amazon S3, Elastic Beanstalk, RDS</td>
<td>Completed</td>
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<tr>
<td>November</td>
<td>Implementation of Web Interface</td>
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<tr>
<td>December</td>
<td>Implementation of Simulation</td>
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<tr>
<td>January</td>
<td>First presentation and intermediate report</td>
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<td></td>
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<td>February</td>
<td>Game Design</td>
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<td></td>
<td>Implementation of API</td>
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<td>Database Migration</td>
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<td>March</td>
<td>Implementation of Google Analytics</td>
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*Table 2. Working Schedule*
7. Conclusion

This report has illustrated the background, motivation, objective, methodology and the complete review of the interactive web application. It aims to enhance teenager’s knowledge and motivation of STEM. Interactivity is the key component of the online learning platform; it is anticipated that interactive web content helps students acquire and pursue STEM knowledge more efficiently.

The application serves as an online STEM learning platform and is accessible by the public to study STEM knowledge. The web interface of application is developed with Angular as the platform and the web API connected to MSSQL relational database is developed with ASP.NET Core as the platform. The application is developed with Amazon Web Services such as Amazon S3, Amazon RDS and Amazon Elastic Beanstalk for Web hosting service.

Simulation, game, animation and video are provided as interactive contents in the application for users to study STEM knowledge. The game score will be recorded by the application and stored in the database for analytical use. Also, the application collect page view data powered by Google Analytics to study the user behavior related to STEM Education.

At this stage, the application provides sufficient features to serve as a learning platform for STEM Education to reach the objectives of this project. But some future works can be made to implement new feature and improve the application to serve the objective.
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