COMP4801

Interim Report

STEM Toolkit with Microbit

Department of Computer Science

University of Hong Kong

Au Ching Mei

3035123227

Supervised by

Dr Vincent Lau

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Abstract

STEM education is important to help students to solve real-life problems with technology. A set of project-based learning materials, STEM toolkit with Microbit (also called STWM), is proposed for children aged from 8 to 13 in Hong Kong. This project aims to raise learners' interest in studying STEM-related disciplines and introduce coding in relation to daily life, with an interactive learning platform as the main focus of the project. This learning website use single-sign-on (SSO) to support user account management and YouTube API. A number of technical difficulties arose during the development, one of which was the video sharing feature. In order to overcome this issue, the YouTube API will be employed. The remaining four tasks to be done in December are testing on YouTube API, setup of web server, organisation the content of the learning materials and implementation of the user interface.

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Abbreviations

API: Application programming interface

FYP: Final year project

IDE: Integrated Development Environment

IT: Information technology

MVC: Model-view-controller

SSO: Single-sign-on

STEM: Science, technology, engineering and mathematics

STWM: STEM Toolkit with Microbit

1. Introduction

STEM stands for Science, Technology, Engineering and Mathematics. In this information era, STEM related products and projects are everywhere in daily life. IT is essential in facilitating the launch of these sophisticated projects. Since the success in STEM can improve economy and livelihood of the country, the demand for experts in this field increases for the sake of the development of the society.

Many countries have raised interests in the field of STEM education in recent years. The United States promotes STEM education and provides tremendous resources to schools in conducting education with STEM. On 25 Sep 2017, White House [1] announced a 200-million-dollar per year commitment to high quality STEM and computer science education. The Education Bureau [2] also encourages STEM education in Hong Kong and introduces it to local primary and secondary schools starting from 2016.

The goal of STEM education is to enable student to solve difficult problems, with the integration of the attitude, knowledge and skills. However, instead of a holistic approach, traditional school curriculum emphasizes on knowledge acquisition only. School teachers might require teaching materials and resources to adapt to the new pedagogy. In response to their needs and concerns, the website is developing for students' self-directed learning of computational thinking.

In Hong Kong, the fields of science, technology and mathematics are included in the curriculum. This paper proposes the key to achieve the goal is engineering and coding. Engineering emphasizes the process to produce the concrete solution and a bridge for learners to link up and apply the knowledge of other disciplines. Coding is the skill required to instruct the computer to perform tasks. Therefore, project-based learning with coding is the main feature in the project.

This FYP project aims to raise learner's interest in studying STEM-related disciplines and introduce coding with linkage to daily life under the modified framework proposed by Grover and Pea [3]. Upon browsing and participating in the interactive activities on the website, students will be equipped with the knowledge, skills and attitude required for problem solving.

As mentioned before, project-based learning is the main approach to teaching in this FYP project. In Hong Kong, traditional STEM related projects in schools are mostly science projects such as paper airplane, water rocket, aquaponics. These projects are well designed to consolidate student's knowledge but they barely have IT elements which constitute an important part in STEM education. In order to introduce IT in STEM, a programmable tool is necessary, and hence the traditional science projects might not be comprehensive solutions for this project.

Two single-board computers were considered, Microbit and mBot. Microbit is designed by the BBC for the use in computer education in the United Kingdom and encourages children to explore and create new things. Therefore, learners can build their own STEM projects alone at home. There is another product mBot which is currently used for STEM education in many schools in Hong Kong.

Table 1 below that compares mBot and Microbit. mBot provides package which is easier for school to manage and use mBot in teaching. On the other hand, Microbit is more flexible. Despite the fact that students may have learnt mBot in school, it is good for them to learn new tool so that they can get used to try new things and other technology.

	mBot	Microbit
Size	Larger	Smaller
Software	Required to install its software, mBlock	No installation as an online coding platform, Microsoft MakeCode, is used instead
Portability	Lower	Higher
Extensibility	High, many mBot extensions are available	High, Microbit has pins to connect to external parts

Table 1. Comparison between Microbit and mBot

In the project, a STEM toolkit with Microbit (STWM) is proposed for children aged from 8 to 13 in Hong Kong. The toolkit includes a printed textbook and an interactive learning website about some basic STEM related disciplines and computer knowledge, tutorials on Microbit, and a few guided STEM projects with Microbit.

Both textbook and website in the toolkit provide knowledge, tutorials and exercises. But the website will be the main focus in this project with electronic features and interactive learning elements. Aside from easy access, website can provide better learning experience. On the other hand, there will be no resources specifically for teachers in the toolkit, as the website emphasizes self-directed learning and aims to reduce teachers' workload. Users of the STWM are expected to have a Microbit to work with throughout the entire learning process. In addition, English is the language used in the whole toolkit. Since when students progress to more advanced textual programming language such as Python, C and Java, strong command in English is required to write code and participate in online forum discussions and collaborations. English is a crucial and practical part of computer education. Therefore, this project aims to also familiarize students with the use of English in the field of IT.

Although there are abundant STEM-related resources online, there are not many suitable self-learning materials on STEM for children as those materials usually require a higher education level in STEM to understand.

Table 2 compares STWM website with two existing related works on the next page. code.org is a powerful platform for youths to learn coding with the designed interactive game-like tutorials, but it does not cover STEM-related disciplines and projects. On the other hand, microbit.org does covered Microbit projects and coding, but it is intended for teachers' use rather than students' use, and the projects and courses are separated. However, the STWM website is designed for young learners to learn STEM through making projects and doing interesting and interactive exercises. Therefore, the STEM website is more comprehensive and suitable in the sense of a self-learning platform in STEM.

	code.org	microbit.org	STWM website
Target users	Young learners	Teachers	Young leaners
Content	Computer science courses	Teaching plans on Microbit projects and computer science courses	STEM course with Microbit projects
Interactivity	High	Low	High

Table 2. Comparison of STWM website and related works

This paper discusses the approach in pedagogy and website, especially the teaching models and interactive features. The overall project progress is evaluated in the project schedule section. There are four tasks to be done in December. After schedule section, the difficulties encountered are discussed, including the use of YouTube API and the copyright issue in video uploading.

2. Approach

This section discusses the teaching approach to STEM education which will be used in this project, and the design and implementation of website and textbook of the toolkit STWM individually in details.

2.1. Pedagogy

As mentioned in the previous section, coding is a part of the STEM education so the traditional science projects may not satisfy the educational goal of STEM. A programmable tool is needed in STEM projects. There are many elements in STEM education, the key is to linked them up by making STEM project. Therefore, the target of the product is to teach STEM with coding by building STEM projects.

The whole learning materials is basically built from Microbit tutorials and its STEM projects. There are lessons in the flow of these Microbit activities. Each lesson holds one fundamental learning key point from STEM-related disciplines or computer science. With the learning key point, the lesson introduce the concept first, then give one or two daily examples and explain, and finally lead to the realization of the idea on Microbit. There are 5-10 lessons and 2-3 STEM projects in total to be done in this project.

The teaching plan provided by microbit.org will be referenced in designing the lesson outline. Since microbit.org is open sourced, the whole toolkit that uses this resource is therefore open sourced.

2.1.1. Engineering Design Process

All STEM projects are problem driven. Learners are motivated to design the solution to the real life problems. There will be guidance to let learners use the engineering design process (see Figure 1) to work on the projects. Besides guiding the learners to do their project, this approach can enhance learners' thinking process of finding solutions to difficult or complex issues with more practices.
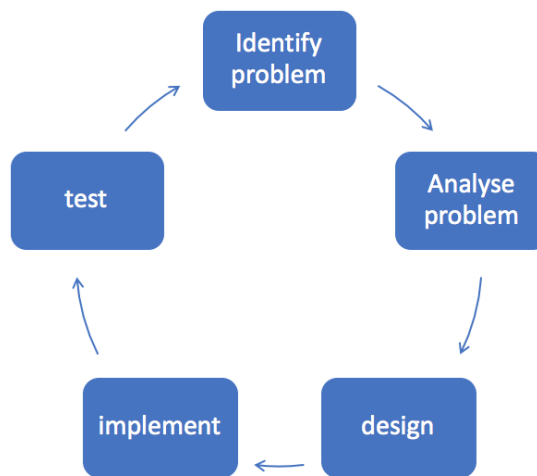
Figure 1. Engineering design process

2.1.2. Attitude, Skills and Knowledge

In addition to state-of-the-art technology and multimedia, a good website for learning requires a solid pedagogical framework. This section aims to further elaborate the choice and adaptation of the Computational Thinking framework proposed by Grover and Pea introduced in the previous chapter.

Table 3 shows the pedagogical framework adapted from Grover and Pea [3] in this project. This framework emphasizes on three main areas in education: attitude, skills and knowledge.

Attitude	Skills	Knowledge
Confidence	Decompositions	Programming
Perseverance	Pattern identification	Algorithm
Expressivity	Abstraction and	Events
Creativity	Generalization	Sequence
Information Literacy	Testing and Debugging	Iteration (Loops)
	Reusing and Remixing	Conditional statements
	Algorithm design	Variables (Data)

Table 3. Pedagogical framework adapted from Grover and Pea

Attitude has often been overlooked by teachers and learners. However, it is an essential quality for solving problems and tackling challenges. Without the right attitude, nothing can be accomplished. With gradual difficulties, the tasks and activities on the website are designed to train students' confidence and perseverance, such that students will find the tasks challenging yet achievable.

The interactive elements on the website avoid direct transfer of knowledge and encourage creativity and expressivity of students. Similar to natural language composition, coding is a creative process as there are often more than one solution to a problem. Throughout the learning journey, the types of questions change gradually from close-ended ones to open-ended ones. While close-ended questions expect students to recall and recite concepts and keywords, open-ended questions expect students to re-apply and eventually integrate the knowledge that they have acquired.

One must not confuse skills and knowledge. Skills are general tools that can be applied to different fields. When students face a huge problem, they are expected to break down the problem into smaller parts and tackle them one by one. This process is called decomposition.

In the project-based learning activities, there will be guiding questions that help students raise questions and divide the project into different parts and stages. After dividing the problem, students will start to realize that they have encountered some of the problems before, of which some of them are generic. This is pattern identification, generalization and abstraction.

On the website, most projects are interrelated to a certain extent, such that beginners can refer to previous projects more easily and extract useful resources. Besides reusing their own code, through the sharing platform on the website, students are encouraged to share their own projects and remix others' project. This practice is common even among professional programmers. They use online platforms such as GitHub and Stack Overflow to share, contribute and discuss each other's program. Everyone is encouraged to reuse and remix others' code, as long as the original creator is attributed. By reading other people's work, students can learn new knowledge and spot common mistakes, which can in turn help themselves debug and improve their own program.

Finally, knowledge is equally important as attitude and skills. In order to write a program that actually works, a solid knowledge foundation is essential. Students are expected to understand and apply basic programming concepts, for example, sequence, iteration, conditional statements and variables. Through making games and gadgets, students learn how to create algorithms that plan and demonstrate the flow of the program. In order to ensure that students understand the concepts instead of blindly copying from the text, there are only limited instructions with blanks to be filled in. These blanks are not necessarily challenging points, but main points that are related to the concepts in question. By filling in the blanks, students realise and reflect the application of programming concepts.

2.2. Website

Basically, the technical objective of the website is to provide an interactive learning platform. Therefore, the main focus is the interactivity. In this project, there are two kinds of interactive objects: computer, and other learners (see Figure 2 below). The STWM website provides better learning experience by using interactive exercises and multimedia in teaching to make learning more interesting. Apart from the teaching part, the website encourages learners to share and review each other's projects. Therefore, the website consists of two main parts, the STEM course with interactive exercises and learners' community. The website also uses single-sign-on (SSO) to support the user account management.
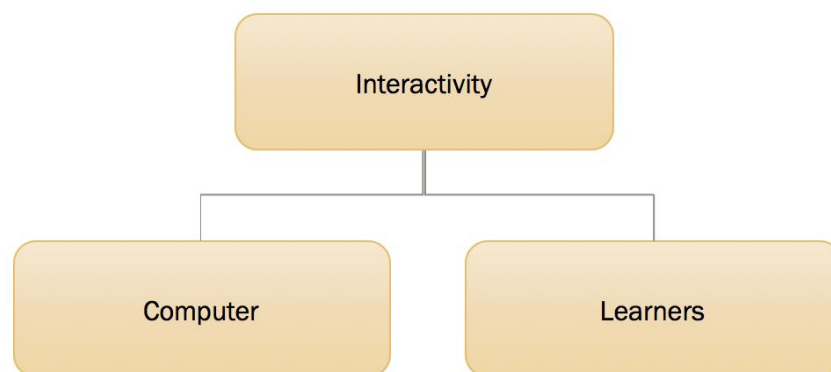

Figure 2. Interactivity of the STWM website includes computer and learners

2.2.1. Interactive Exercises

For the STEM course, one of the major feature of the website is the interactive exercise, to make learning more interesting. Apart from question-answer type of exercise, activities such as mini games, simulations, and more will be introduced to the website. In order to make the content attractive to young learners and let them be engaged in learning, the website uses more multimedia, including graphics, videos and animation to present programming concepts that are often formal and abstract.

For example, in order to explain the concept of variables, instead of giving the definition only, metaphors are often used. One of the most common analogies is fruit baskets: A basket stores fruits. We can add and take away fruits from the basket. Each basket contains only one type of fruit. This concrete

comparison can be animated to explain the concept of variables, which store values of a specific data type.

Moreover, the website can let users to trace their study progress in the course easily by saving the data in database. The study progress is presented graphically with "health bars" in bright colours similar to those in video games, which can be stimulating and encouraging as they give a sense of achievement.

Nevertheless, interactive exercises are not mutually exclusive with traditional question types such as multiple-choice, fill in the blanks, matching and sentence-type questions. These basic question types can consolidate students' knowledge base as a means of debriefing at the end of each chapter and bring students back to the academic context. Efforts will be made to make these traditional questions more lively.

For example, multiple choice questions can be presented in the style of "Who wants to be a millionaire", with lifelines such as "50-50" and "Ask the audience". Also, some easier multiple choice questions can be timed in order to increase the difficulty and somehow speed up the learning progress.
In addition to text, questions can be asked in the form of audio, video or image, which can reduce the language barrier that science-oriented students often encounter.

Games facilitate students to understand concepts, but traditional questions enable the process of abstraction as students need reflect on and explain the abstract concepts in their own words in order to re-apply them in situations other than the games.
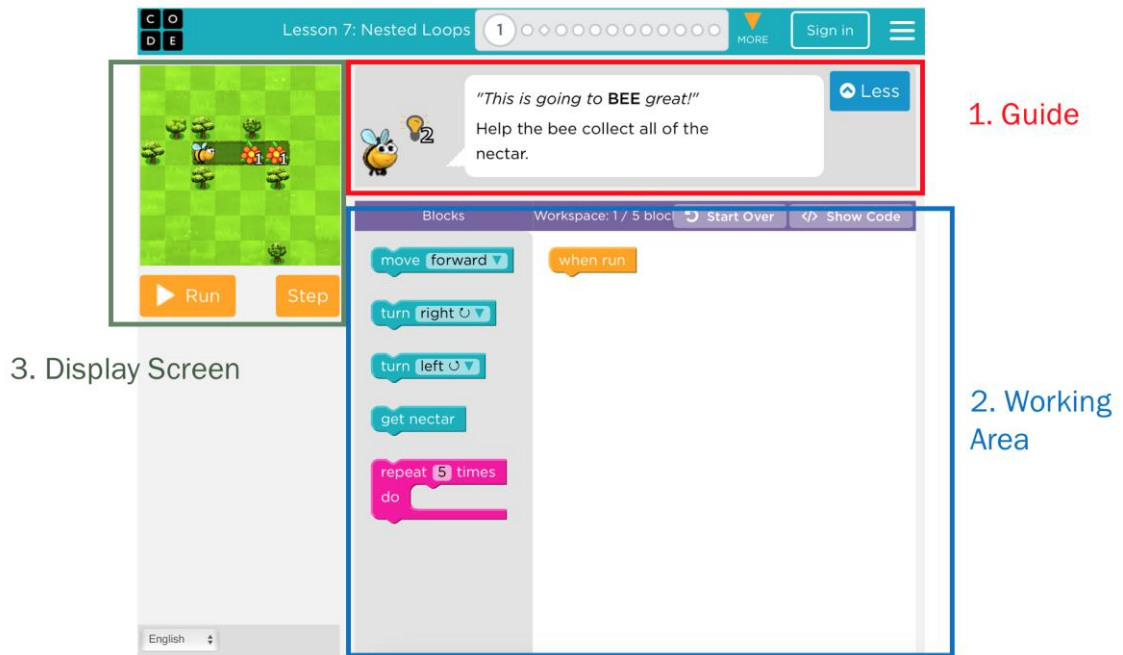
Figure 3. Example: interactive exercise in code.org

Taking code.org as an example (see Figure 3), the user interface of the interactive exercise used in this project also consists of three parts: guide, working area and the display screen.

First of all, the guiding window can teach the user how to use this interface and show the current task. This window can also be used as to give hints and message if any.

Secondly, there should be a clear panel for user to work on. Refer to Figure 3, the working area allows user to write a program by dragging and dropping the coding blocks.

Last but not least, it is important to display the result of user's work. The display screen can show the performance of user's program. Therefore, user is able to tell if the result is expected or not, and the display screen is useful for user to debug their programs.

2.2.2. Learners' Community

For the learners' community, users can share their STEM projects by uploading videos and Microbit programs. Learners can search, view and comment on shared projects. It is important for learners to record their projects and demonstrate it. Their approach to the solution can be shown in the videos.

Sharing of videos can encourage learners to learn from and be inspired by each other. In addition, by testing and commenting on each other's program, students can gain experience and feedback, which can enhance their debugging skills.

Compared to the traditional learning mode, collaborative learning is more superior. Traditionally, since the teacher has to examine more than 30 projects per class, students often receive little and brief feedback from the teacher, which might not be not fruitful both qualitatively and quantitatively. With the learners' community, on top of the teacher's comments, students can help each other by giving more practical advice from their learning process, which is often overlooked by highly skilled IT teachers.

2.2.3. Single-sign-on (SSO)

The website supports single-sign-on (SSO) which allow users to login with one single identity. Instagram is one example of SSO. Users can login Instagram with their Facebook account. SSO can ease the troubles of managing multiple accounts that users often encounter, especially children. It is not necessary for users to create and remember a pair of username and password just for the STWM system.

In the STWM website, learners can simply sign up with SSO. Even though learning materials have been made available to the public, user accounts benefit users by allowing them to keep track of their study progress. One might argue that client-side based technologies such as cookies can already record user data and does not increase the server load. However, user accounts are more suitable to modern society. In present days, many people in Hong

Kong, including children, own more than one electronic device with internet access, for example, desktop computers, tablets and smartphones. In order to ensure a smooth transition between different platforms, a cloud-based user account system is required.

There are three SSO service providers considered, namely Google, Microsoft and Facebook. All of them are very popular and the services are commonly used. Google can do SSO to access all its cloud resources and online service, such as Gmail, Google Drive and YouTube. Microsoft focus more on SSO dealing with the issue of multiple accounts for the identical user on computer, Microsoft Office software and Office cloud services. Facebook itself is a social networking site. More importantly, both Google and Microsoft provide free education services for Hong Kong local primary and secondary schools. In other words, most Hong Kong students are already using Google or Microsoft services as their school intranet account for e-Learning purpose, so they do not have to sign up for a new Google or Microsoft account and are not likely to forget their username and password.

Microsoft SSO mainly focus on desktop accounts and Microsoft Office accounts which are irrelevant to this project, only the email service is useful. Facebook SSO allow users to share the webpage on the social network. Although not necessary, this can be a bonus feature for students to share and discuss their learning progress or outcome on social media, which allows the STWM website to become part of their personal life, encouraging them to invest more time on programming and promoting the project on the social networking site.

Both Google and Microsoft have advantage over Facebook as they can allow the system to reach the users by email. Since STWM website is a self-learning platform, young learners may easily distract and forget the website without monitoring. By sending colourful email reminders with encouraging and playful messages, it can encourage learners to keep up with their study. Compared to Microsoft, Google is more suitable to STWM website in the sense that learners can upload video with their Google account by using

YouTube API. It can reduce the storage burden of the system and take advantage of the stable HD streaming service provided by YouTube. But at this moment, using the YouTube API in video uploading is possible, and more trials runs and tests are required to examine if this method works according to expectations.

2.2.4. Responsive Web Design

Responsive web design refers to the use of auto-resizing scripts to adapt a web page to different widths [4]. This approach aims to tackle the varying sizes of different devices. As mobile devices became popular, mobile web browsing had to be taken into account. In the local school context, schools are gradually adapting to e-Learning with tablets, so Hong Kong children are likely to use tablets at school, smartphones on the bus, and desktop at home. In response this wide range of sizes, responsive web design was developed to dynamically resize the width of a web page according to the width of the viewport. Apart from line wrapping of the text, multimedia elements such as videos and images are shrunk to fit the screen, so users do not have to scrolling left and right but only up and down. Moreover, the models, brands and browsers of these devices vary individually. Therefore, in order to ensure accessibility by all devices available in the market, a responsive web design is required for the STWM website.

2.2.5. Technical Aspect

For the development of the website, a popular PHP-based framework, Laravel, is used. Laravel can simplify the setup of the system when compares to pure PHP development, as Laravel has simpler syntax, easier approach in routing and managing database, MVC pattern and higher security.

For the SSO part, login is easy to do using OAuth2. This function has been tested and will be integrated into the website. However, the video upload to YouTube is still undergoing investigation. Basically, HTML, PHP, CSS, JavaScript, MySQL and Bootstrap are used to make the interactive content and responsive website.

The STWM system will be based on a web server to host the website. Refer to Figure 4 below shows the website architecture, user uses a web browser to access the server and view the web files. In order to login the system, the server will redirect user to Google for authentication. If the user is authenticated, Google will pass the email address and the access token to the server. The email can be used as a primary key to identify a user, and the token will then be updated for the corresponding user entry in the database. With the email and access token, the server can access Google service within the life time of the token. Most likely the service used is the upload of video to YouTube here. Sending emails does not need the token.
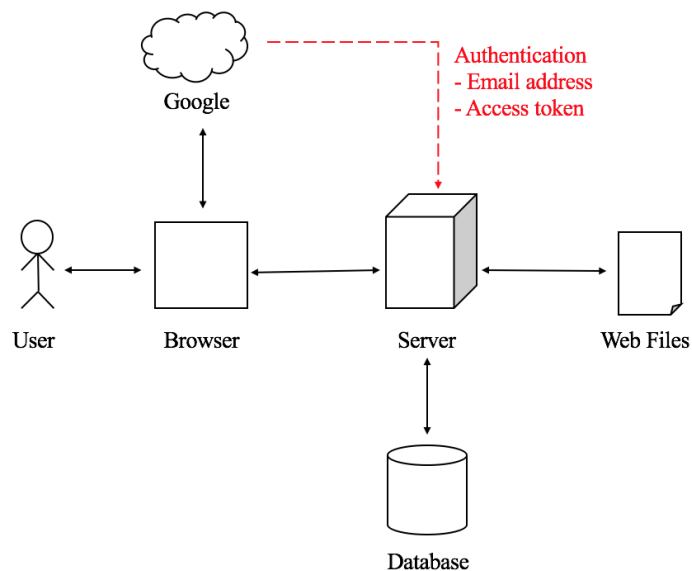

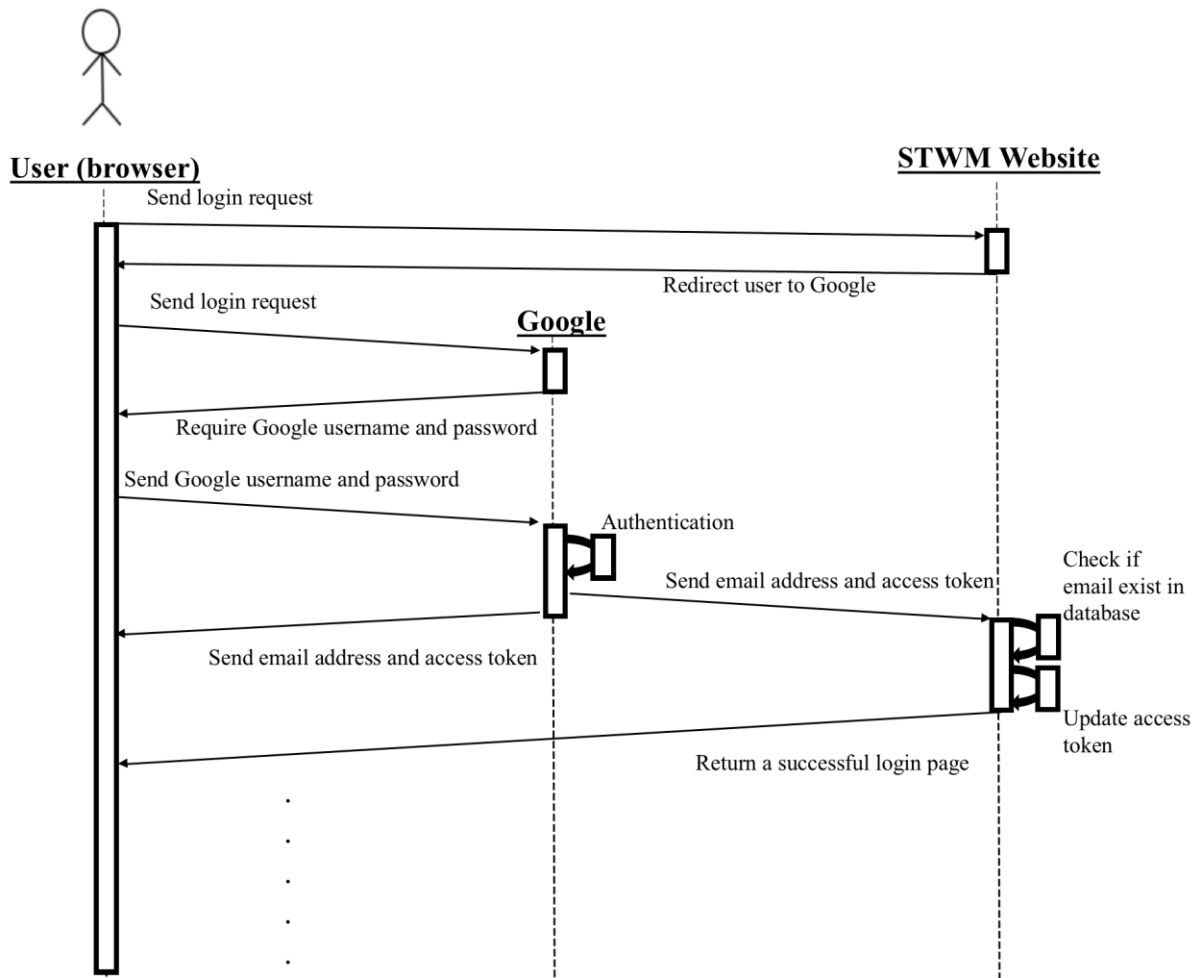Figure 4. Website architecture diagram

Figure 5. System sequence diagram of successful login with Google SSO

Figure 5 shows the system sequence diagram of successful login with Google SSO. Google verifies if this is a valid Google user and STWM website then checks if this Google user is also a STWM user. Therefore, there is two barriers in authentication. If the user fails to login Google, Google has to handle the follow up of the failure in login. If the user logged in Google but this Goggle account is not registered in STWM website yet (in other words, STWM receives an email address from Google but cannot find the corresponding email address in the database), STWM will return a register page to the user. After the user agrees the terms of uses in the register page, a new corresponding user entry will be inserted to the user table in the database, and STWM will return the successful login page to the user.

2.2.6. Testing

There are two tests for the website. The first one is the technical test which test for the functionality of the website. The second one is the user task analysis which invites 10 students and 3 teachers to use the website and collects their feedbacks. The evaluation focus on two aspects: interface design and learning materials covered in the website, as it is important that user know how to use the website and the learning materials is well-designed.

2.3. Textbook

Considering that it is a self-learning toolkit, the design of the textbook has to be colourful and attractive, yet simple and informative. The printed materials are expected to be interesting and attractive to young readers, so the main tone can be casual and the design style can be more cheerful. There will also be some storylines and cartoons in the textbook between sections and hence increase the readability. The textbook will be edited after the development of the website. There is nothing done yet on textbook.

3. Schedule

Table 4 shows the schedule of this project. As seen from the table, the design of the website is completed and the implementation of the website is in progress. However, the project is behind schedule and the holiday in December should be well spent in order to catch up the progress. Otherwise, the website implementation will not be able to be completed by December as scheduled.

Website Design	Sept-Oct	Completed
Website Implementation	Oct-Dec	In Progress
Testing	Jan	Not Completed
Textbook	Jan-Feb	Not Completed
Adjustment	Jan-March	Not Completed

Table 4. Project schedule

There are four upcoming tasks in December. The first one is the testing of the YouTube API in the video uploading section of the learners' community. The second task is to setup of the web server. These two tasks should be completed within 10 days. The third task is to confirm the content of the learning materials in the STEM course, and this task should be completed within a week as it is simply to organise the materials. After finishing the three tasks, the implementation of the user interface can be started.

4. Difficulties

One of the biggest challenge in this project is how to do teach in order to satisfy the goal. The proposed method for STEM education is to learn from building STEM projects which try to solve real-life problem. This method has been tested on site by providing STEM training to secondary students, and it is effective judging from the feedbacks. The next step will be to use this experience to make the teaching and learning materials for self-directed learning and encouraging students to program in their spare time.

As a self-learning online platform, communication and sharing among learners are important in making improvement and learning from each other. Thus, the website is designed to have a project sharing feature. However, sharing source codes is not sufficient to achieve the goal as a good project does not solely rely on the program. There should be a way for learners to present their projects comprehensively. Therefore, an idea of uploading video is proposed. Video recording can demonstrate how the project works lively. It is the quickest way to know a new project.

In addition, copyright is an another issue in the project sharing section. Since learners can view each other work, it is foreseeable that copying is possible to occur. Meanwhile, learners can also be inspired by the others' projects and have their ideas of enhancement or adjustment on the original work. If it is the case, the original work should be referenced in the modified work. However, the Microbit IDE, MakeCode, does not support this feature. Up to this moment, a proposed solution is to introduce a referencing mechanism in the website. This referencing mechanism relies on the users to do the referencing if their project to be uploaded is an alteration of another project. Moreover, in order to promote information literacy and respect of intellectual property, whenever a user opens the source code created by someone else, a clear reminder will be shown. They will not be able to access the code unless they click agree to follow the attribution rules.

At this moment, our team is struggling on how to provide the function of video uploading. At first, PHP was used to perform this task and it worked. However, some trial runs encountered problems in uploading videos with large size. Moreover, it is realized

the requirement on the server's storage will be greatly increased if the videos are stored in the server.

But then, YouTube, which is the largest video sharing site in the world, is proposed. It is feasible that learners can first upload the video onto YouTube, and then they can simply share the video link to the website. This can solve the storage problem.

And now, with the SSO feature added, videos upload to YouTube inside the STWM webpage is considered, and research and trial runs on the YouTube API is progressing. If the implementation with YouTube API fail, the method of sharing YouTube video link is the backup plan.

5. Conclusions

The project-based teaching approach and self-learning website are illustrated. An engineering approach is used in guiding STEM projects. Interactivity is the technical objective of the website. There are two interactive features in the website: interactive exercises (computer) and learners' community (other learners). Meanwhile, the website has SSO to support user management and video uploading.

Using Google SSO, users need not remember a new pair of username and password as they can login with their Google Accounts. With the user account, the learning progress of each user is saved and can be traced back in anytime. A friendly email reminder will be sent to the user when they have not shown up in the website in a long time. Therefore, using SSO can make STWM website more user friendly. In addition, SSO benefit the website in reduction on storage burden as videos can be uploaded to YouTube using YouTube API.

Overall, the project is behind schedule, therefore, more works should be done in December. The remaining four tasks to be done in December are testing on YouTube API, setup of web server, organisation the content of the learning materials and implementation of the user interface.

6. References

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