Analysis and Design of Collaborative STEM Learning Based on a 2D Virtual Environment in Teacher Team Delivery

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ABSTRACT

With the Thai government and education policy investigating ways to drive Thailand towards an innovative and creatively based society, STEM education has become increasingly an important learning method. Typically, STEM education implementation requires teachers to be expert in STEM areas to helps to bridge the gaps sometimes found in STEM-related fields. Moreover, STEM educators have increasingly sought to explore tools and techniques to enable creating suitable approaches to promote STEM engagement. Simultaneously, two-dimensional virtual environments have been applied in various disciplines and areas of study. This has led to the essential approach - how is a 2D virtual environment developed and how does it handle delivering and supporting collaborative STEM learning and communication between STEM students and STEM-related field teachers? The aim of this project is to collaborate with learning processes across different STEM learning fields. In this work we describe the development and deployment of a 2D virtual environment tool to bring diverse STEM teacher teams and STEM students to learning together. This project proposes an interactive multimedia STEM instructional module developed to provide a delivering and supporting collaborative STEM learning and communication between STEM students, and STEM-related field teachers. This module was built following the interaction design principle to create instructional material for learning based on 2D virtual environment in teacher team delivery. Unity was used to create the 2D virtual environment and containing a learning digital media, control learning digital media using C#. This project can support those who teach STEM and those who are considering collaborating with learning processes across different STEM learning fields. Besides, the student results summary report indicated an improvement in STEM learning and learning accomplishments of content for five instructional objectives.

Keywords: *virtual environment, collaborative learning, information seeking behavior, human computer interaction, STEM education*

INTRODUCTION

With Thai government and key education policy in Thailand trying to elevate Thailand to become an innovative and creatively based society, STEM education has become an increasingly important learning method (Ministry of Education Thailand, 2017). To enhance and elevate Thailand into an innovative and creatively based, Thailand must prepare the young generation by strengthening the foundation of creativity and innovation along with foster student’s interest in science and technology (Kamal et al., 2018). It is important for students especially, at an early stage of education to generate the students’ analyzing skills via STEM education starting at the school level (Lensing & Friedhoff, 2018). Typically, STEM education implementation requires teachers to be expert in the STEM areas of science, technology, engineering and mathematics to help to bridge the gaps sometimes found in STEM-related fields. STEM educators have increasingly sought to explore tools and techniques to enable creating suitable approaches to promote STEM engagement (e.g. Altan, 2016; Ejiwale, 2013). Simultaneously, two-dimensional (2D) virtual environments (VE) have been applied in various disciplines and areas of study such as healthcare, multimedia information system, and education (e.g.Hoppe, 2020; Kang, 2015; Zhang, 2018). While the rapid advancement in learning technology is ready to promote STEM engagement in the formal classroom, there are numerous

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obstacles to implementing new teaching techniques and learning technology (Subramanian et al., 2012). For example, incorporating learning in STEM teacher team delivery across different STEM fields is constrained by geographical locations and tedious scheduling (Liaw et.al., 2019). This has led to the essential approach of understanding how 2D -VE have been developed, and how they handle delivering and supporting collaborative STEM learning and communication between STEM students, and STEM-related fields teachers.

An important question in this new educational movement is whether using a 2D -VE would improve the delivery of collaborative STEM learning activities and supporting communication between STEM students, and STEM-related fields teachers. More importantly, how they will build collaborative teamwork and communication for supporting STEM learning activities. Thus, it is necessary to find the way to deliver STEM teacher teams that may support collaborative STEM learning. The aim of this project is to collaborate learning processes across different STEM learning fields in order to help to bridge the gaps sometimes found in STEM-related fields, in this work we describe the development and deployment of 2D -VE tools to bring a diverse STEM teacher team and STEM students to learn together. This project is to analyze and design the virtual STEM learning base in a 2D -VE in teacher team delivery. Engagement of students in STEM education, curriculum, instruction, and assessment are required to for blending the aggregates, as well as integrate engineering and technology into the science and mathematics curriculum (Kennedy & Odell, 2014). Thus, if incorporating learning in STEM teacher team delivery across different STEM fields is constrained by geographical locations and tedious scheduling (Liaw et.al., 2019), 2D - VE is a potential tool to bring diverse STEM students to learn together (Hoppe, 2020). The aim of this project is to develop a virtual STEM learning base on a 2D virtual environment in teacher team delivery.

LITERATURE REVIEW

We briefly review the foundation and main framework that addresses the issues related to the 2D - VE for collaborative STEM learning.

2 Dimension

Though 3D VE is more lifelike than 2D. Yet, cost of software and the lengthy time scales needed to produce 3D animation. The 3D applications such as a virtual or augmented reality (VR/AR) are developed for the display hardware setups. This limits content and standard software such as web browser that is obtainable on a 2D desktop, because not every standard application can be accessed using VR or AR (Hoppe, 2020). However, comparing to 3D-VE, 2D allow available content to be played by a larger audience as less demand for 2D and easier to run on a 2D desktop PC. This allows the developers to spend more time focusing on story. Thus, providing faster load times, we focus on 2D run on a desktop PC as a 2D in the VE. This allows a 2D-VE is a potential tool for collaborative learning and engaging students in more education (e.g. Hoppe, 2020). 2D can helps to solve the lack of experimental resources in the educational area (Li, 2017) and provides students with a chance for investigative experiments. Because the experimental equipment and the experimental environment are virtual simulations, the investigator does not need to concern about the damage factors of the experimental equipment but can carry out experiments as the experimenter likes (Zhang, 2018).

STEM Education

Thailand as one of the ASEAN members has realized the importance of STEM education to prepare the human resources to be competitive labors in the future. The policy of developing science and technology has been announced to support Thailand 4.0 era (IPST, 2013). As such, STEM education is become one of the key components in supporting Thailand 4.0 era in the 21st century under education THAILAND 4.0 framework (Ministry of Education Thailand, 2017; Sritrakul, 2018). STEM education implementation requires teachers to be expert in the disciplines of science, technologies, engineering and mathematics. The research in this field seeks to improve STEM instructional practice and identify the challenges that arose during the implementation (Ramli et al., 2017). The STEM learning process helps us to teach innovation and creativity to students (e.g. Sias et al., 2017; Chen et al., 2016). Developers and STEM teachers must attempt to 1) prepare STEM implementation; and 2) to develop tools and techniques to enable the creation of suitable approaches (Altan, 2016; Ejiwale, 2013). Moreover, prior research result showed the problem of STEM education are some primary schools haven't had any experiences about STEM activities before. Teachers acknowledge the proactive movement of STEM education in schools but there still were many of teachers who shortage of knowledge and understanding about STEM (He et al., 2017). Accordingly, STEM education did not mandate complete STEM learning, and the encouragement of STEM activities was neglected (Office of the Minister, 2016; Sritrakul, 2018). STEM teachers still needed academic issues, budget, and personnel development. Teachers and supervisors have to change their learning management focusing more on the integrations (Mustafa et al., 2016).

Interaction Design Process

In the interaction design process, there are various principles used to be guidelines to help developers in the designation of any type of instructional material for learning delivery (Lashley, 2019). For example, Martin, Hoskins, Brooks, and Bennett (2015) proposed the ADDIE design process (analysis, design, development, implementation, and evaluation) to helps users in the creation and development of learning material for any type of learning delivery. This model provides a roadmap for the entire instructional design process. Preece, Sharp, and Rogers (2015) indicated that the interaction design principle is communication between a user and a system where the system has an interface that is both user-interested and, like a conversation between human, as well as an intermediary between user and system. Moreover, Donald Norma's Interaction model concentrates on User's view of the interface indicated that the user interface view consists of 7 steps i.e., 1. User to establish Goal, 2. User to formulate Intention, 3. Decides on action on the interface, 4. Executes the action, 5. Perceives system state, 6. Interprets system response, and 7. Evaluates system with respect to goal. The Abound and Beale' interactive framework extends from the Norman model. This framework has described the reality of interaction with the system more specifically. In their theory, it is divided into 4 main parts: user, input, system and output, each with its own language, system part having core language, and user part having task language. And the output has its own language where these two parts are combined into an interface. Besides, ergonomic design (Elbert et al., 2018) is a designing the workplace to fit the needs of the user rather than trying to adjust user to fit the workplace. More importantly, aspect ratio is another reason that it is very essential because it influences how developers compose photographs and how big they are going to be. Aspect ratio describes the width of an image in relation to its height. It is always important to note the aspect ratio of the device when preparing images and videos for the design. Thus, in this paper we consider a variety of theories, for example the ADDIE process (Martin et al., 2015), the Interaction design principle (e.g. Early & Zender, 2008; Blair & Zender, 2008). Donald Norman's Interaction model (Norman, 1986,1988) Abowd and Beale framework (Abowd & Beale, 1991) and ergonomic design (e.g. Soares & Rebelo, 2016) Human -Computer Interaction (e.g. Dix et al., 2004) as well as aspect ratio theory (e.g. Berger, 2019) are guidelines when designing interactions for delivery of STEM instruction.

RESEARCH METHOD

Subjects

Due to of the fact that the COVID19 pandemic obstructing the invitation of 30-50 elementary students as participants in the study, we decided to invite 3 STEM experts from different fields of science, technology, engineering and mathematics to incorporate into this research for providing STEM identity.

An Interactive Multimedia STEM Instructional Module Development Process

In this project we follow a variety of theories such as the ADDIE process (Martin et al., 2015) as a guideline to develop the interactive multimedia STEM instructional module as following.

1) The analysis phases

This project has four steps to analysis learning environment used as the evidence for decisions-making process of design and development in the interaction media instructional content (Martin et al., 2015) as follow.

Analysis: In Thailand, “content standards” and “Integrated unit” in elementary school with Grade, or Year 2, with the content of “How to cook Salak loykaeow” has shown “What student should know and be able to do”. This STEM content: “How to cook Salak loykaeow” are experiments or science labs in which the learning processes are doing something other than listening. Students must gather and practice science, technology, engineering, and mathematics in surroundings that make connections between the classroom and the real world around them (Ministry of education, 2017). The goal is to see students working in an integrative way. Based on an “integrated unit”, it indicated that teaching and learning should combine various subject areas with corresponding topics or issues (Ritz & Fan, 2015; Bell et al., 2017). Teachers are able to link various learning materials and process such as reading, speaking and writing together (Sias et al., 2017). However, incorporating leaning in STEM teacher team delivery across different STEM fields is constrained by geographical location and scheduling (Liaw et.al., 2019) As a result, many students leave out on this unique educational opportunity.

Proposed solution: To consider the holistic development of students, we are exposed to a variety of activities that enable students to learn new things (Benitez et al., 2020). With the advent of new-age technologies and teaching methods, the holistic development of a student elementary schools has involved physical experience such as moving and touching movements that occurs in response to conscious learning from the five senses (Reese & Dunn, 2007). Moreover, if we analyze the Integrated Unit in elementary schools with Grade 2 with the content of “How to cook Salak loykaeow” that requires showing “What student should know and be able to do” (Ministry of Education Thailand, 2017), we found that when “how to cook Salak loykaeow” was integrated it provided potential for turning a lesson into a physical experience that the students could use in the real world (Liaw et.al., 2019; Ministry of Education Thailand, 2017). Thus, interactive multimedia STEM instructional module developed may provide a delivering and supporting collaborative STEM learning and communication between STEM students, and STEM-related field teachers. By delivering STEM teacher team within a graphic animation the STEM learning process will be able to helps us to elevate students to become more innovative and creative.

Audience analysis: This module is designed to attract students, especially from elementary school. Due to of the fact that students have different learning ways to receive, process, understand, and retain new information (Dunn, 2009). Some prefer to learn by doing things than other method, some by reading and others by asking questions. However, a common thing for all students is that they learn best when they can incorporate topics or items that interest them in their studies (Tyas & Safitri, 2017). Moreover, kinesthetic learning is one of various learning styles that the involvement of the learner's body movement can results in new knowledge or understanding. More importantly a kinesthetic activity can help ingrain learning into long-term memory by turning a lesson into a physical experience (Tyas & Safitri, 2017). Student is engaged in a kinesthetic activity by moving and touching and interacting with their lessons, and a great side benefit is that kinesthetic learning activities are usually lots of fun (Reese & Dunn, 2007). Thus, this module used to provide students with knowledge of STEM and/or provide reinforcement activities during interacting with multimedia STEM instructions.

Goal analysis: This module is designed to support bringing diverse STEM teacher teams and STEM students to learn together and deliver STEM teacher teams that may support collaborative STEM learning.

Instructional setting analysis**.** This module is used by STEM teachers and students planning better class sessions for STEM learning. A desktop PC computer (Graphic Card) and Internet access is needed. Additionally, a smart LCD touch screen of 55 inches. An additional advantage is that each screen contains content that will attract elementary students, and support learners who lack literacy skills. Moreover, researchers analyzed the height of elementary students standing while interacting with the multimedia STEM Instruction that relate to visual and auditory use via LCD monitors. It showed that elementary students of age range from 7- 9 for males 122cm – 133.5cm and for females 121.5cm -133cm high respectively. Thus, a tripod should be used and adjusted to suit for students.

2) Design phase

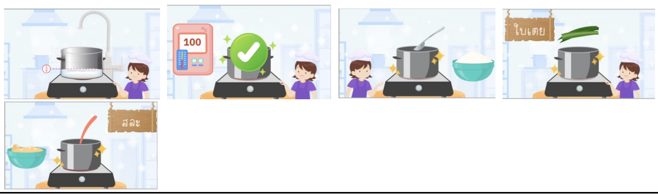
After the comprehensive analysis phase, the design phase was followed up immediately. The information gained from the analysis phase is translated into a plan for the instructional program (Martin et al., 2015).

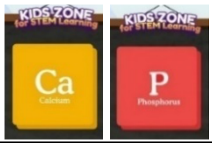
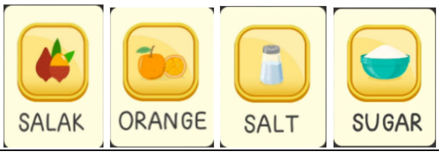
Instructional objectives: We used the instructional objectives as a starting point to focuses on student attention and the perception of lesson content. Students should be informed that after they finished the instructional process, what it is that they are going to be able to do (Reiser & Dick, 1996; Hannafin & Peck, 1988). Thus, the first step, we determine the sequence of objective that helps to create the outline of the instructional material (Nesbit & Hunka, 1987). After the sequence of objective has been determined, information of instructional content and activities for each objective identified are selected. Then, the instructional objectives, information, and descriptions of activities are transferred to storyboards (Martin et al.,2015).

Design assessment aligned with objectives: Herman, Aschbacher, and Winters (1992) indicate that when students know the goal of the instruction they perform better and can compare their performance to the standard. Thus, in this instructional material, assessments were designed to evaluate the instructional objectives.

The objectives were identified and aligned with the assessments before the instructional content was developed (Table1).

Table 1: Objectives and assessment for the interactive multimedia STEM instructional module

Instructional Objective	Assessment
1. Students can identify the characteristics of the Salak tree.	Direction: Choose the correct answer for this question by touching in the checkbox to the right of the statement. Is this the characteristics of the Salak tree ? Yes ▢ No ▢ 
2. Students can explain the process of cooking Salak loykaeow.	Direction: match the number from the top to its picture of the process for cooking Salak loykaeow by dragging and dropping the number onto the correct image. **1 2 3 4 5** 

Instructional Objective	Assessment
3. Students can explain equipment for cooking Salak loykaeow.	Direction: Choose the correct answer for the question by touching onto the correct image. Which is the equipment for cooking Salak loykaeow? 
4. Students can explain benefit from Salak.	Directions: Pair the name of the benefit from Salak to its image by dragging and dropping them onto the correct picture. Calcium Phosphorus 
5. Students can explain about the ingredient of Salak loykaeow	Direction: Choose the correct answer for the question by touching onto the correct image. 5. What kind of main ingredient is the most important for cooking Salak loykaeow? 

Moreover, in the design phase, an outline of the content was developed to identify different sections of the module and describe the topics that were to be listed in each section (Table 2).

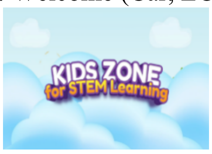
Table 2: The outline of content for the interactive multimedia STEM instructional module

	Sections	Depiction
1	Introduction	**Welcome** (Car and LOGO) Introduction to how to cook Salak loykaeow and telling the importance of this learning unit. STEM teacher takes the students to the kitchen.
2	Phase One	the ingredients for cooking Salak loykaeow. Display in letter: Salak, Sugar, and Pandan leaf. Display images: Salak, Sugar, and Pandan leaf
3	Phase Two	the process of cooking Salak loykaeow. Put water into the pot. Turn on interactive- electric stove Boil water Put sugar into the pot. Put pandan leaf into the pot. Put salak into the pot. Display Salak louKaew was done.
4	Phase three (STEM)	Alternate between question and STEM Instructional Question1: what is the equipment for cooking Salak loykaeow? STEM Instructional1: fraction (Mathematic)
5	Phase four (STEM)	Alternate between question and STEM Instructional Question2: what temperature to boil water? STEM Instructional2: boiling point of water (Science/Engineer)

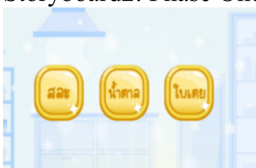
	Sections	Depiction
6	Phase five (STEM)	Alternate between question and STEM Instructional Question3: what are the ingredients for syrup? STEM Instructional3: solvent (Engineer/Technology)
7	Phase six (STEM)	Alternate between question and STEM Instructional Question4: what is the ingredient having an odor for cooking Salak loykaeow? STEM Instructional4: pnadan leaf (Science)
8	Phase seven (STEM)	Alternate between question and STEM Instructional Question5: What kind of main ingredient is the most important for cooking Salak loykaeow? STEM Instructional5: Salak (Science)
9	Phase eight	Location, children library suggestion type of book and motivate to read

The example of storyboards for depicting screens from the interactive multimedia STEM instructional module.

Storyboard1: Introduction: Welcome (Car, LOGO and STEM Teacher)


Storyboard2: Phase One: The ingredients for cooking Salak loykaeow.




DEVELOPMENT AND IMPLEMENTATION

The Process of The Interactive Multimedia STEM Instructional Module

The procedure for each of the logical sequence in the interaction of the STEM learning system as Table 3.

Table 3: The process of the interactive multimedia STEM instructional module

Main flows	Students	System
	1. Students enroll by entering the student number.	1.1 Verify student ID status.
	2. Students learn how to cook Salak loykaeow from interactive multimedia STEM instructional module	2.1 The system displays interactive multimedia STEM instructional module to provide students with knowledge and understanding of the process of cooking Salak loykaeow.
	3. Students interact with multimedia STEM instructional module to perform the process of cooking Salak loykaeow.	3.1 The system verifies the correct process of cooking Salak loykaeow that students have performed correctly, then the raw data have to be stored in the database.
	4. Students interact with multimedia STEM instructional module to take an examination.	4.1 The system verifies the correct answers and will be graded according to the number of times that students have performed correctly, then the

Main flows	Students	System
		raw scores have to be stored in the database.
Alternation Flows	Step 2 re-viewing: if students have finished watching the process of cooking Salak loykaeow, then students can press the button to view again. The system will start showing learning media again. Step 2 pause: while students are watching media, they can press the pause button and continue watching again.	
Exception Conditions	Step 1 The system will alert when the student does not fill in all fields.	

Development of The Graphics and Cartoon Characters

In this case, Adobe Illustrator was used to design all graphics and cartoon characters, and Adobe After Effects was used to animate scenes and text in this instructional game. There were many components used in the design of the creative multimedia STEM instructional games i.e., 1. STEM characters were created as friends of children. 2. A simulated scene was designed to be as colorfully similar to the real thing as possible with bright colors, and 3. Buttons, icons, elements were added to be interesting in the instructional game.

Color psychology and feelings (Psychology of Color)

The target group of creating interactive media games for creative learning is elementary school children. Therefore, there is a design concept that makes the target audience interested and has a design concept using multimedia STEM instruction with character designs, colorful scenes suitable for children of this age to make children interested which encourages children to want to learn more.

The STEM content is about learning to cook Salak loykaeow by using an interactive multimedia STEM learning game. When children have simulated the process of cooking it, they will be able to remember the objectives (Reese & Dunn, 2007). In psychology, color is a stimulant and affects the human mind. It means different colors give different feelings. For example, red gives a feeling of fervor, violence, danger, and excitement; yellow gives a feeling of light, warmth, clarity, cheerfulness, faith, wealth. Therefore, we often use colors to convey feelings and meanings.

Mood and tone of images

Game and characters were designed with a bright tone, but they still use cool tone colors for designing gaming scenes. Because the cool colors will make it possible to stare for a long time while playing games, making it more comfortable for the eyes. as well as creating a character to be with children at elementary school age.

The primary colors are 80% cool and 20% warm. Cool colors are designed to be soothing blue, and it is a color that gives a feeling of being clear and bright (Blair & Zender, 2008) (according to the psychology above). However, the design of kitchen appliances such as water boilers, gas stove lights, etc, it was design with the warm colors and contrast with the cool colors to make the overall concept look more real world.

Mood and Tone of interactive multimedia STEM instructional module

The content is about STEM content learning about how to cook Salak loykaeow. With the content about kitchen equipment and fruit (Salak), it was designed using bright colors to attract the attention of children. The choice of color should also be consistent with the mood of the user or the target audience. Therefore, the psychology or sentiment of color of the target audience should be considered to make the design work as successful as possible (Hannafin & Peck, 1988; Blair & Zender, 2008).

The Example of Screenshots of Scene from the Interactive Multimedia STEM Instruction

Below is the example of screenshots of scene from the interactive multimedia STEM instruction module with sound effects sound, and verbal commands.

The start of the interactive multimedia STEM instructional game is designed as a school bus with the logo “KIDS ZONE LEARNING STEM” to convey the meaning of school buses that are transporting students to a kids zone for learning STEM. The scene focuses on bright colors to create interesting and attractive to the students (Figure 1).

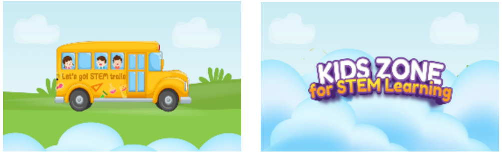


Figure 1: The opening scene and Logo of "KIDS ZONE LEARNING STEM"

Characters (STEM teacher) introduce themselves and tell the importance of this interactive multimedia STEM instructinal game (Figture 2).

Figure 2: Characters introduce themselves (STEM teacher)

The STEM teacher takes the students to the graphic animation kitchen and asks them "Have you ever cooked Salak loykaeow? and how did you make it? STEM teacher explains what kind of ingrediants are used (Figure 3).

Figure 3: STEM teacher take the students to the graphic animation kitchen.

Then the process of cooking Salak loykaeow was display with STEM teacher explanation as follow.

Step 1: start the process of cooking Salak loykaeow. The STEM teacher explains to students to prepare for cooking Salak loykaeow. Then, the STEM teacher tells the student to turn on the virtual kitchen tap sink and put some water into the pot by touching (pressing) the virtual kitchen tap sink on the touchscreen. While the STEM teacher explains the amount of water needed for cooking Salak loykaeow, the learning media displays the amount of water 1:4 of pot. Whenever the amount of water is at the correct level the learning media shows the corret icon (Figure 4).

Figure 4: STEM teacher explain amount of water for cooking Salak loykaeow.

Step 2: the STEM teacher ask student to turn on virtual electric stove by touching (pressing) the switch of the virtual electric stove on the touchscreen. Then teacher explains to students to boil the water until at the level of boiling point:100 degrees Celsius (Figure 5).

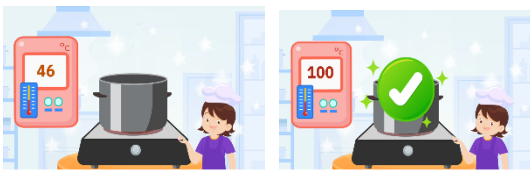


Figure 5: Water's boiling point is 100 degrees Celsius

Stem 3: the STEM teacher ask student to put some sugar into the pot by dragging and dropping some sugar on the touchscreen. Then teacher explains to students to simmer sugar until syrupy. (Figure 6)

Figure 6: put some sugar into the pot and simmer sugar until syrupy

Step 4: the STEM teacher asks students to put pandan leaves into the pot by dragging and dropping pandan leaves on the touchscreen (Figure 7).

Figure 7: Putting pandan leaves in the pot

Step 5: the STEM teacher explains to students to put Salak into the pot by dragging and dropping Salak on a touch screen (Figure 8).

Figure 8: putting pandan leaves into the pot

Step 6: the STEM teacher shows the Salak LoyKaew that has been completed from the cooking process (Figure 9).

Figure 9: The scene showing the Salak Loykaew that has been completed from the cooking process.

After finishing explaining and doing all of the processes of cooking Salak loykaeow, the STEM teacher will let students answer the 5 questions related to Salak loykaeow (Figure 10-14). The students choose the correct answer from the teacher in the real class along with STEM teacher module. Then alternate with delivery STEM teachers to educate STEM content.

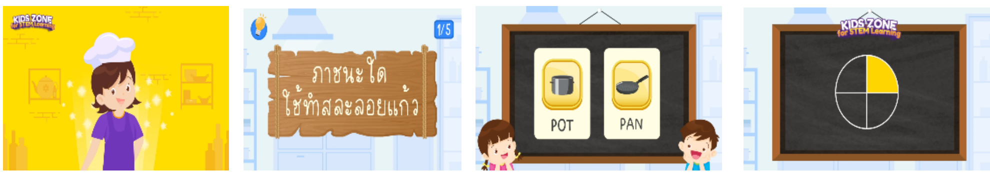


Figure 10: STEM Teacher asks the questions 1 what is the equipment for cooking Salak loykaeow?

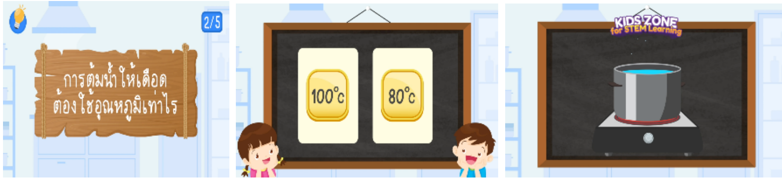


Figure 11: Question2: what temperature to boil water?

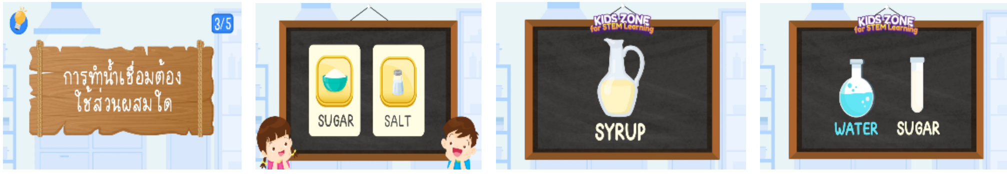


Figure 12: Question3: what are the ingredients for syrup?

Figure 13: Question 4: what is the ingredient with an odor in cooking Salak loykaeow?

Figure 14: Question5: What kind of main ingredient is the most important for cooking Salak loykaeow?

After finishing answering all of the questions in previous phase, the STEM teacher will tell students to go to the school library to persuade them to read or even look up information on how to cook Salak loykaeow as well from various books that can provide the knowledge they want. (Figure 15).

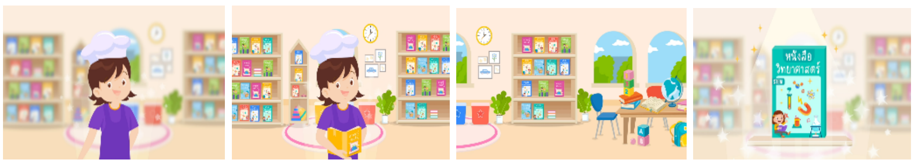


Figure 15: the STEM teacher will tell students to go to school library and bookshelf

Implementation

Implementation requires several components: a) web application IIS; b) Microsoft SQL Server Express and c) an "Salak loykaeow" application system for STEM education learning, using UNITY and containing a learning digital media, control learning digital media using C# (Figure 16).

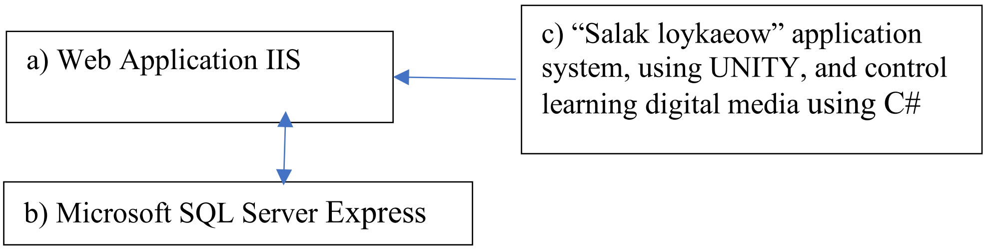


Figure 16: Architectural frameworks provide support for implementing

Software

Web application: Web application was developed with ASP.NET CORE MVC Framework by programming a computer in C# language and installing the web application in IIS so that teachers can access the registration information and the scores of the students through the web application.

Microsoft SQL Server Express: is a version of Microsoft's SQL Server relational database management system.

UNITY: Unity is a cross-platform game engine for developing 2D and 3D video games and creating simulations on PCs (desktop and laptop). Unity uses C++ to write the main parts and has C# overlaying functions such as sound, logic, and functionality of the game that developers want.

Internet Information Services: IIS is a program on windows OS that acts as a web server to open web site services through web browsers and provide services over protocols, such as HTTP.

Hardware

The equipment used to interact with the interactive multimedia STEM instructional module. Monitor stand used to support 55-inch monitor, with height adjustable; touch screen LCD display monitor with 55-inch and computer PC with graphic card (Figure 17).

Figure 17: The equipment used to interact with the interactive multimedia STEM instructional module

Evaluation Methods

Online pretest and posttest design**:** With the COVID19 pandemic stopping researchers going to STEM schools to participate in the evaluation process, it was decided to conduct both online evaluation (pre and posttest) and online interviews. The online evaluation was completed first, and then the online interviews were done to ensure the pretest and post-test by objective and the robustness of the data coming out of the online interviews (Duffy & Smith, 2003; Martin, Hoskins, Brooks, & Bennett, 2015). The pre- and post-tests were an online form and responses were collected electronically. They included 5 items included STEM content. The pre and post-test was sent to participants via the Line application. Students were given identical pre- and post-tests at the beginning and end of the program. To prevent potential bias in scoring, pre- and post-tests were done in random order.

Participants: The pre- and posttests included 40 participants. The demographic information of the participants included 22 female, and 18 male, grade 2 students, from Sarasas Witaed Burapha

School and Piboonbumpen Demonstration School, Burapha University. Participants were recruited to take part in the study through personal contract and scheduling. All 40 elementary students completed the online pre- and post-tests and the brief online interview. The University's Human Subjects Committee approved this experimental protocol, and all participants signed an informed consent before their participation in this study.

Online pretest and posttest procedures: First, students were given an identical pretest at the beginning, the pretest was sent to students via the Line application, then researcher asked the parents to display the multimedia STEM instructional video to their child (about 10 minutes). After that, students were given identical post-tests. The post-test was sent to students via the Line application. The responses were collected electronically.

The findings of Evaluation

Table 4 show the student results summary report from the online pretest and post-test by objective. This result indicated an improvement in STEM learning for five objectives. Students accomplished learning of content for objective 1 (100% on post-test); however, their performance on the rest objectives was adequate. In fact, the second most learning is objective 5, followed by objective 3, 2 and 4 respectively (see table 4).

Table 4: the student results summary report from the pretest and post-test by objective.

Instructional Objective	**Pretest Mean**	**Posttest Mean**
1. Students can identify the characteristics of the Salak tree.	100%	100%
2. Students can explain the process of cooking Salak loykaeow.	66.5%	75.0%
3. Students can explain equipment for cooking Salak loykaeow.	74.3%	85.0%
4. Students can explain benefit from Salak.	57.9%	65.0%
5. Students can explain about the ingredient of Salak loykaeow	77.0%	88.0%
Totals	75%	83%

Student's opinion from Online Interview: After elementary student Grade 2 finished the pre- and post-tests, the researcher then evaluated the student's attitude toward the multimedia STEM instructional game. During the online interview, students were asked to express their thoughts about multimedia STEM instruction. These comments captured student's opinions. The following words reflected student's attitudes and perception of learning. For example, 'the sound effect of the multimedia STEM instructional game was very attractive and made me awake, not sleepy." Interestingly, some students commented, "After I learned from the multimedia STEM instruction, I should have an opportunity to make Salak loykaeow as well." This may account for students focus on doing rather than only listening. Moreover, the parents also expressed their impression of quality and characteristic on the interesting features that they had viewed while opening the module for their children.

CONCLUSIONS

With government and education policy in Thailand calling for the ways to build Thailand into an innovative and creatively based society, STEM education has become an increasingly important learning method (Ministry of Education Thailand, 2017).

This project provides a prototype for designing and analyzing of collaborative STEM learning base in a 2D - VE for teacher team delivery. The aim of this project is to collaborate learning process across different STEM learning fields in order to help to bridge the gaps sometimes found in STEM-related fields.

This paper proposed teacher training with a face-to-face interactive multimedia STEM instructional module developed to support collaborative STEM learning and communication between STEM students and STEM-related field teachers. This module was built following the steps of AADIE process that helps to create learning delivery for the instructional material. Unity was used to develop the 2D-VE interaction multimedia program. This project will strength those who teach STEM and those who are considering collaborating on learning processes across different STEM learning field.

According to reflections from students and their parents, students have a positive attitude and good perception of learning as the sound effects of the multimedia STEM instructional game can attract and make them wake up. This may mean that using a 2D - VE can improve in delivering collaborative STEM learning activities, and supporting communication between STEM students, and STEM-related field teachers. Interestingly, After, they learned from multimedia STEM instruction, they preferred to make Salak loykaeow rather than only listening. This may account for students focus on doing rather than only listening and touching.

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