The Development of Engineering Design Process on Web Application Learning Model to Enhance Web Programming Skills for Computer Education Students

Noppadon Phumeechanya* and Sumalee Soonthara

***Abstract*—The purpose of this research is to 1) develop an engineering design process on web application learning model to enhance web programming skills for Computer Education students; 2) develop a web application for use in the engineering design process-based learning model; 3) evaluate the students' web programming skills; 4) compare students' learning achievement before and after learning with the developed learning model; and 5) study the students' satisfaction with the developed learning model. The research sample was 30 undergraduate students majoring in Computer Education at Nakhon Pathom Rajabhat University, obtained by cluster sampling. The research instruments consisted of 1) an engineering design process on web application learning model; 2) a web application; 3) a web programming skills assessment test; 4) a learning achievement test; and 5) a satisfaction assessment. The statistics used were mean, standard deviation, and t-test. The results showed that 1) the engineering design process on web application learning model has the highest level of appropriateness. 2) The quality of the web application used in the engineering design process-based learning model is at a very good level in content and technical aspects. 3) Students' web programming skills are higher than the set criteria of 80%. 4) Students' learning achievement after learning is higher than before with a statistical significance level of 0.05. 5) Students are satisfied with the learning model at the highest level.**

***Index Terms*—Engineering design process, web application, web programming skills**

I. Introduction

Programming skills are one of the most important skills in the digital age. They help learners to improve their problem-solving and logical thinking which is essential in today's computing practice [1]. According to the World Economic Forum, technology design and programming skills will be one of the top 15 skills by 2025 [2]. Programming skills are part of the information and communication technology skills included in 21st-century learning skills. Programming skills will help young people grow up as a population in the digital age who can make the most of information technology to solve everyday problems and create innovations from computer technology [3]. Today, there are many forms of program development, e.g., personal computer programming, web programming, and mobile application programming. Particularly, web programming skills are necessary for web developers, as well as computer student teachers who need the skills to teach students in schools [4].

In Thailand, the computer and technology curriculum in basic education has been improved to be consistent with the changes of the world. The Thai government has promoted teaching and learning with STEM education, which integrates Science, Technology, Engineering, and Mathematics (STEM) in education [5]. The Institute for the Promotion of Teaching Science and Technology (IPST) promotes basic skills in using technology to innovate creatively. The engineering design process has been promoted in teaching management [6]. It is a teaching management method to enhance and develop the learner's learning. The engineering design process focuses on various problem-solving methods and encourages the learner to use their own ability to create innovations. There are a series of steps guiding the learner to successfully solve the problem [7]. The engineering design process also provides teaching and learning that aligns with STEM education [8–10].

According to research studies on the application of engineering design processes in teaching and learning management, it was found that this makes teaching more effective, enhances scientific creativity, and increases collaborative abilities [11]. It is appropriate to apply the engineering design process to teaching and learning because it is a method of teaching and learning that focuses on real-world practice for students and helps develop critical thinking and problem-solving skills [12]. Therefore, it is suitable to be used in teaching and learning to develop web programming skills.

Nowadays, teaching management technology is rapidly evolving. Web-based teaching is a method of remote learning based on an internet network that provides learners with access to learning resources at any time, from anywhere, and it is well-suited for use during the COVID-19 pandemic [13]. The application of web-based teaching in various subjects has been found to generate great interest in the learner. It promotes classroom atmosphere and significantly increases participation in teaching activities [14]. Additionally, using web applications in conjunction with learning management systems enhances effective learning environment and classroom activities and motivates students both inside and outside the classroom [15]. From the research study, it was found that web applications can be used in teaching management to develop web programming skills [16].

From the experience in teaching the Web Page Design and Programming Courses for Computer Education students, Faculty of Science and Technology, Nakhon Pathom Rajabhat University in the academic year 2020, it was found

Manuscript received March 22, 2023; revised April 17, 2023; accepted June 1, 2023.

Noppadon Phumeechanya and Sumalee Soonthara are with the Department of Computer Education, Nakhon Pathom Rajabhat University, Nakhon Pathom, Thailand.

*Correspondence: noppadon@npru.ac.th (N.P.)

doi: 10.18178/ijiet.2023.13.10.1964

that some students had moderate to low-level web programming skills. Therefore, the researcher has the intention to develop a new learning model by applying modern web application technology and the concept of engineering design process-based learning. The model emphasizes the learners' practice and enables the learner to create work from their skills and abilities. This helps improve the web programming skills of Computer Education students to be used in their future careers.

II. Research Objectives

1) To develop an engineering design process on web application learning model to enhance web programming skills for Computer Education students.
2) To develop a web application for use in the engineering design process on web application learning model to enhance web programming skills for Computer Education students.
3) To evaluate the web programming skills of Computer Education Students after learning with the developed learning model.
4) To compare the learning achievement of students before and after learning through the engineering design process on web application learning model.
5) To study students' satisfaction after learning through the engineering design process on web application learning model.

III. Literature Review

A. Engineering Design Process

The engineering design process is the steps of learning as a team to solve a particular problem. It allows learners to solve problems by applying their knowledge to create challenging innovation. The engineering design process is a series of steps to identify problems, then develop and improve the best solution to a problem. Each step can be repeated to improve the solution [7, 17]. The engineering design process encourages learners to have a thinking process, resulting in good problem-solving thinking ability [18, 19]. Students learn happily and love learning [8]. There is a number of researchers who have developed the steps of the engineering design process. For example, Teach Engineering [7] proposed 7 steps of the engineering design process. They are 1) ask: identify the need and constraints, 2) research the problem, 3) imagine: develop possible solutions, 4) plan: select a promising solution, 5) create: build a prototype, 6) test and evaluate the prototype, and 7) improve: redesign as needed. Museum of Science Boston [20] proposed the steps of the engineering design process are as follows: 1) ask, 2) imagine, 3) plan, 4) create, and 5) improve. The prominent step is to create a prototype and test its operation. Students have learned from creating work pieces to solve everyday problems. In this research, the engineering design process is synthesized to develop a learning model.

B. Web Application

Web technology plays an important role in learning management today. Currently, web applications are developed to run on a variety of devices, allowing learners to access through any platform, whether Personal Computer (PC), notebook, tablet, and mobile phone. It increases the convenience for learners to learn anytime, anywhere. Web-Based Learning Model (WBL) has been applied in learning management and it helps improve learning achievement [21–24].

Due to the COVID-19 pandemic, many educational institutions have adopted online teaching methods to reduce the spread of the virus. Web-based learning has, therefore, played an important role in teaching and learning activities [13]. Learners can participate in learning activities on web pages, e.g., studying lesson content, doing exercises, and taking exams. In organizing learning on a computer programming course, students can learn programming theory and practice through web pages [25]. In other words, web pages are one effective tool for organizing learning activities. This research has applied web technologies to develop a web application as a primary tool for learning. Students do the engineering design process-based activities through the developed web application.

C. Web Programming Skills

Programming skills are important for computer teachers as they teach programming courses in schools [26, 27]. Particularly, web programming skills are essential for computer student teachers in teaching students in schools. The evaluation of web programming skills gives an indication of web programming proficiency of computer student teachers. Web programming skills assessment criteria have been developed for evaluating web programming by several educational institutions, e.g., the University of Wisconsin [28] and California State University [29]. The topics of evaluation comprise the content interest, the use of images, graphics, internal and external links of the web, the correct coding of programs, etc. In this research, criteria for web programming skill evaluation have been synthesized for evaluating students' web programming skills. The topics are 1) web programming skills and 2) web design skills.

IV. Methodology

This research is experimental research. The one-group posttest-only design is for studying web programming skills, and the one-group pretest-posttest design is for studying web programming achievement.

A. Research Sample

The population was 396 undergraduate students majoring in Computer Education at the Faculty of Science and Technology, Nakhon Pathom Rajabhat University, who were studying in the second semester of the academic year 2021, the sample was 30 undergraduate students enrolled in Webpage Design and Programming, derived by cluster sampling.

B. Research Instruments

1) An engineering design process on web application learning model to enhance web programming skills for

Computer Education students, consisting of a learning model and a learning management plan of 8 units in the Webpage Design and Programming subject.

2) A web application for engineering design process for students to access and conduct learning activities according to the developed model. The web application can be run on a variety of devices, including PCs and mobile devices.
3) A web programming skills assessment form for evaluating students' web programming performance after learning through the developed model. It will assess 2 aspects: 1) web programming skills and 2) web design skills.
4) A learning achievement test for evaluating students' achievement before and after learning through the developed model. It is a multiple-choice form with four options and 60 questions.
5) A student satisfaction assessment form with the developed engineering design process model on the web application.

C. Research Phase 1: Develop Model and Web Application

1) The development of the engineering design process on web application learning model to enhance web programming skills comprised the following steps.

1.1) The study and synthesis of the conceptual framework for the engineering design process-based learning model on a web application to enhance web programming skills included studying relevant documents and research and interviewing five higher education teachers. The results of the interview were used as information to develop the learning model.

1.2) The development of a prototype of the engineering design process-based learning model on a web application to enhance web programming skills for Computer Education students included synthesizing the steps of engineering design process-based learning in Table I:

TABLE I: THE SYNTHESIS OF THE ENGINEERING DESIGN PROCESS

Billar Hubelbank oliva [8]	Museum of Science Boston [20]	Kareemee [30]	Science Buddies [31]	Teach Engineering [7]	Synthesis Learning Process
Identify the Problem/Need	Ask	Problem Identification	Define the Problem	Ask: Identify the Need & Constraints	Define the Problem
Research and Rank Objectives and Constraints		Related Information Search	Do Background Research	Research the Problem	Related Information Search
Develop Possible Solutions	Imagine	Solution Design	Specify Requirements	Imagine: Develop Possible Solutions	Develop Possible Solutions
Select the Best Solution within Constraints	Plan	Planning and Development	Brainstorm Solutions	Plan: Select a Promising Solution	Planning and Prototype Development
			Choose the Best Solution	Create: Build a Prototype	
Construct a Prototype/Model Solution	Create		Develop the Solution		
			Build a Prototype		
Test/Evaluate the Solution		Test, Evaluation and Design Improvement	Test and Redesign	Test and Evaluate Prototype	Test and evaluation
Present/Communicate the Results		Presentation	Communicate Results		Presentation
Redesign and Revise	Improve			Improve: Redesign as Needed	

Regarding the synthesis of the engineering design process, it consists of 6 steps: 1) define the problem, 2) related information search, 3) develop possible solutions, 4) planning and prototype development, 5) test and evaluation, and 6) presentation. These steps were used to organize learning activities in conjunction with web-based learning. Eight learning management plans based on the developed learning model were prepared. The content of the learning management plans consisted of 1) internet and web technologies and web development with HTML, 2) web development with CSS language part 1, 3) web development with CSS language part 2, 4) form creation, 5) web development with PHP language, 6) web development with databases part 1, 7) web development with databases part 2, and 8) publishing websites on the Internet.

2) The development of web applications for engineering design process-based learning for Computer Education students using the principles of design and development according to the Systems Development Life Cycle (SDLC) [32], divided into 5 phases as follows:

2.1) Requirement analysis was the study of concepts and theories and data collection for developing web applications for engineering design process-based learning by studying, analyzing, and synthesizing documents and data in web application development technologies that were currently available, working models, and functions.

2.2) System and software design was the analysis of data obtained from the need analysis and the application of the results to design a web application. The system and software design comprised 1) system architecture design, 2) database system design, entity relationship diagram design, and data storage structure design, 3) Graphic User Interface (GUI) design, and 4) lesson content design.

2.3) Implementation and unit testing was the development of web applications using HTML, CSS, and JavaScript. It included the development of web applications in a responsive web design using the bootstrap framework so that the developed web application could run on all

devices using the MySQL database [33, 34]. The developed web applications served as learning materials and learning management systems, as well as learning data storage, e.g., students' pretest and posttest data.

2.4) Integration and system testing was the quality and system performance evaluation using the black box testing techniques. The test consisted of 1) unit testing, which validated each part of the system, 2) integration testing, which was the joint operation of the program, and 3) system testing, which tested all functions in the system, constructed from all sub-programs. The web application was presented to the experts for quality assessment and the web application was assessed the effectiveness (E1/E2).

2.5) Operation and maintenance was the installation of the developed web application on the webserver ready for teaching according to the developed learning model.

The system of web applications shown in Fig. 1.

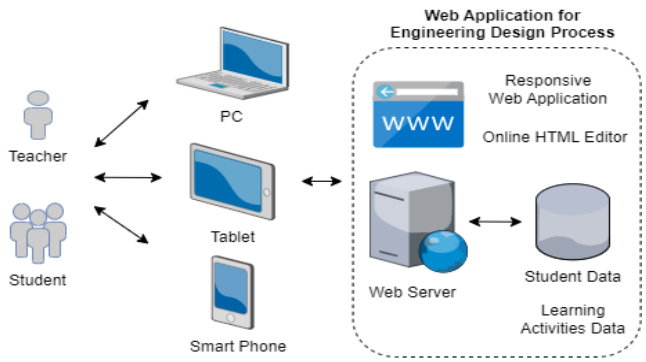

Fig. 1. The system of web applications for engineering design process-based learning.

3) The development of scoring rubrics for assessing students' web programming performance. The assessment topics were 1) web programming skills and 2) website design skills. The assessment form for web programming skills was presented to the experts to assess the consistency between the question and the objective (IOC).

4) The development of the achievement test gave 80 four multiple-choice questions. The test was presented to the expert to assess the consistency between the question and the objective (IOC). The achievement test had difficulty (p) between 0.43–0.79 and discriminating power (r) between 0.29–0.86. The reliability value of the whole test according to the KR-20 formula was 0.95. 60 questions were selected as the achievement test.

5) The development of the assessment form for student satisfaction with the developed learning model adopted Likert's five-rating scale. The questionnaire was presented to the experts to assess the consistency between the question and the objective (IOC).

A. *Phase 2: Collection of Experimental Data from the Developed Learning Model*

Phase 2 of the research is the collection of experimental data from the developed learning model, consisting of the following steps:

1) Students take a pre-test on the web application, 60 questions, taking 60 minutes.

2) The teacher organized learning according to the learning management plans and the developed learning model through the web application for the period of 2 hours per week for 8 weeks.

3) After learning, students took the post-test on the web application, 60 questions, taking 60 minutes.

4) Students were evaluated web programming skills by developing the application according to the assigned problem. The teacher then assessed the students' performance using the web programming skills assessment form, with a full score of 40 points.

5) Students conducted the questionnaire to assess satisfaction with the developed learning model.

6) The scores from the web programming skill assessment form were analyzed using one sample t-test and compared with the set criteria of 80%.

7) The scores from the pre-test and post-test were analyzed using paired sample test.

8) The satisfaction scores were analyzed using mean and standard deviation.

V. Research Result

A. *Result of Research Phase 1*

1) The development result of the engineering design process on web application learning model to enhance web programming skills (as shown in Fig. 2).

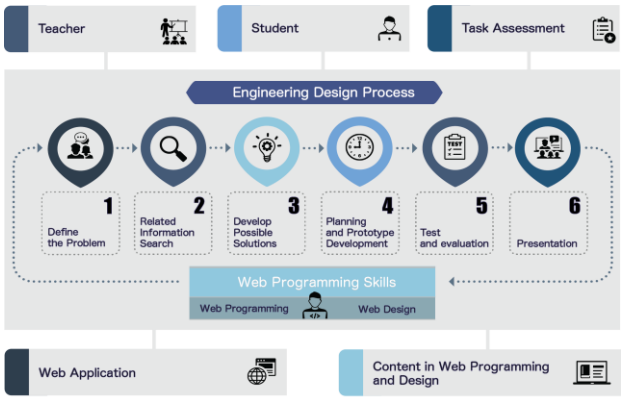

Fig. 2. An engineering design process on web application learning model to enhance web programming skills for computer education students.

The elements of the learning model were as follows:

a) The teacher conducted the teaching according to the lesson plans based on the engineering design process-based learning on the web application. Students were required to learn and perform various activities on the developed web application according to the 6 Steps of the engineering design process. The teacher followed up on the progress of learning through the web application and assisted when learners experienced problems in performing activities.

b) Students, majoring in Computer Education, performed learning activities according to the learning model by studying the theory and practicing web programming on the web application. After the learners completed each lesson, they performed group activities as determined by the teacher. Students conducted web development

activities according to the engineering design process and submitted the assignment on the web application.

c) Learning activities based on the engineering design process on the web application consisted of 6 steps as follows:

i) In defining the problem step, the learner studied the problem of developing a website based on information from the learner's daily life and they addressed the problem that would be solved using the website. This step adopted the principles of 5W1H questioning [35], consisting of 1) who is the question asking about the person, 2) what is the question of what the problem is or need for developing the website, 3) when is the question of when the website will be used and at what time, 4) where is the question of where the website will be used or where is the user, 5) why is the question to analyze the reason why the website needs to be developed, and 6) how is the question to analyze the solution or how to solve the problem with the developed website. The learner answered the questions on the web application.

ii) In related information search step, learners collected the relevant and necessary information for developing the website. Learners searched and collected information from various sources to use for developing the website. Students practiced searching for information from various sources and screened information that was necessary for the further development of the website.

iii) In develop possible solutions step, group members jointly designed solutions through the website structure design and navigation menus. Students practiced web programming skills in website design, a part of web programming skills. The sub-skills include: 1) designing the page layout, 2) designing navigation and linking systems, 3) designing content presentation method, 4) designing graphic images, and 5) designing consistency of each page.

iv) In planning and prototype development step a students planned and divided the duties of the group members to develop the website prototype. They divided up the tasks and operated on their assignments. Students practiced web programming skills in the following sub-skills: 1) HTML programming skills, 2) CSS programming skills for website decoration, 3) PHP programming skills for database integration, 4) database system design skills, and 5) Graphic User Interface Creating Skills (GUI). The developed web application provided instructional materials for students to study the computer programming sample and test the computer program instantly.

v) In test and evaluation step, students tested the developed website to know what needs to be improved. The defects were recorded and corrected. Students then submitted the test report and used the result for improvement.

vi) In presentation step, website development method was proposed and used to solve various problems. The students in group summarized the solution and presented the website development method by recording a website development video of their group and posting the video on the web application so that the teacher and other students could come to see the presentation.

d) The content of Web Page Programming and Design Course consists of 1) internet and web technologies and web development with HTML, 2) web development with CSS language part 1, 3) web development with CSS language part 2, 4) form creation, 5) web development with PHP language, 6) web development with databases part 1, 7) web development with databases part 2, and 8) publishing websites on the Internet.

e) The web application could run on any device. It also worked with the database system to store student information, learning progress, students' score, and group assignment submission. Students could study the lesson on the web application from anywhere at any time and could submit tasks through the web application. Moreover, students could work together as a group and submit their tasks on the system so that the teacher could check the score through the system.

f) Task assessment was conducted from the students' website development using the web programming skill assessment form. The teacher assessed students' tasks based on the rubric criteria in the specified topic to indicate the students' web programming skills reflected in the tasks.

g) Web programming skills reflected in the students' website development. The topics used for assessment were web programming skills and website design skills. Web programming skills could be evaluated using the web programming skill assessment form using rubric criteria.

The assessment result of engineering design process-based learning model on web applications to enhance web programming skills shown in Table II.

TABLE II : THE ASSESSMENT RESULT OF ENGINEERING DESIGN PROCESS ON WEB APPLICATION LEARNING MODEL TO ENHANCE WEB PROGRAMMING SKILLS FOR COMPUTER EDUCATION STUDENTS

Assessment Items	$\bar{x}$	*S.D.*	Level of Appropriateness
1. Principles and concepts used as the basis for the learning model development	5.00	0.00	Highest
2. The main components of the learning model	4.71	0.57	Highest
3. Learning activities based on the engineering design process-based learning on a web application	4.83	0.38	Highest
4. Measurement and evaluation	4.80	0.45	Highest
5. The developed learning model appropriate for the development of web programming skills for undergraduate students	5.00	0.00	Highest
6. The steps and activities of the developed learning model appropriate for the development of web programming skills for undergraduate students	4.80	0.45	Highest
7. The developed learning model feasible in practice	4.80	0.45	Highest
Total	**4.85**	**0.45**	**Highest**

2) The development result of the web application for use in the engineering design process on web application learning model.

From the development of the web application for use in the engineering design process on web application learning

model, the developed web application can be used on personal computers and mobile devices as shown in Fig. 3.

The web application consisted of the following: 1) Web programming learning materials in 8 topics, where learners could practice coding HTML and CSS online and the programming results could display instantly in the live preview, increasing the convenience of learning HTML programming. 2) Learning activities based on the developed learning model with the engineering design process on the web application had 6 steps. In each step, learners could learn together in groups, do learning activities, and submit tasks through the web application. 3) Learners took the learning achievement test through the web application. According to the results of web application quality assessment before the trial, the content ($\bar{x}$ = 4.86, S.D. = 0.35) and the technical ($\bar{x}$ = 4.88, S.D. = 0.33) aspects were at a very good level . The result of the effectiveness assessment (E1/E2) was 81.04/80.50 which met the set criteria of 80/80.

B. Research Results Phase 2

1) The result of students' web programming skill evaluation after learning through the developed learning model

The result of students' web programming skill evaluation is shown in Table III.

Table III shows that students' web programming skills are higher than the set criteria of 80 percent, with an average of 33.70 points out of 40. When considering the sub-skills, students have an average of 16.83 points in web programming skills, higher that the set criteria of 80 percent, and an average of 16.87 points in website design skills, also higher than the set criteria of 80 percent. The students' web programming skills score shown in Fig. 4.

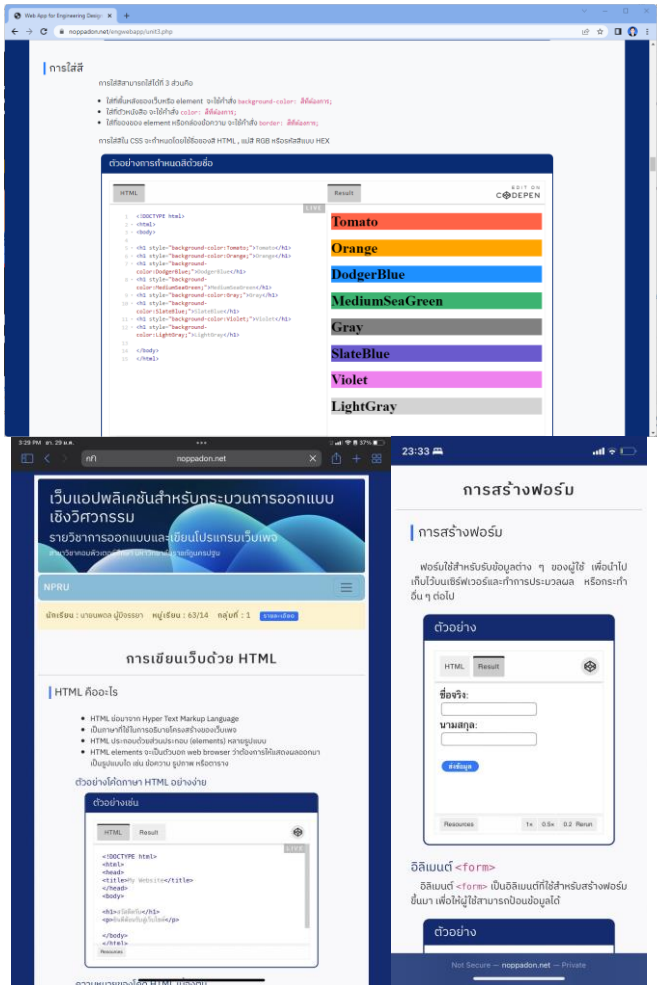

Fig. 3. The web application for use in the engineering design process on web application learning model.

TABLE III: THE RESULT OF STUDENTS' WEB PROGRAMMING SKILL EVALUATION

Item Evaluation	N	Score	Test-value (80% of Score)	$\bar{x}$	S. D.	t-test	p-value
1. Web Programming Skills	30	20	16	16.83	1.29	3.54	0.00*
2. Web Design Skills	30	20	16	16.87	1.43	3.31	0.00*
Overall	**30**	**40**	**32**	**33.70**	**2.26**	**4.12**	**0.00***

* $p < 0.05$

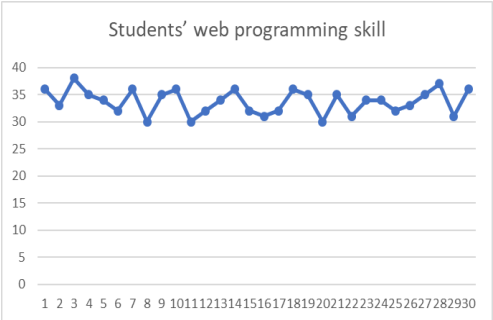

Fig. 4. The students' web programming skills score.

2) The results of comparison of students' achievement after learning through the engineering design process on web application learning model.

The results of the students' pre- and post-test are shown in Table IV.

From Table IV, students' learning achievement after learning with the developed model is higher than before with the statistical significance level of 0.05, with the average score of 42.87 points out of 60. The students' learning achievement score shown in Fig. 5.

TABLE IV: THE RESULTS OF STUDENT ACHIEVEMENT AFTER LEARNING THROUGH THE ENGINEERING DESIGN PROCESS ON WEB APPLICATION LEARNING MODEL

Testing	N	Score	$\bar{x}$	SD	t-test	p-value
Pretest	30	60	16.77	3.70	28.36	0.00 *
Posttest	30	60	42.87	4.95		

* $p < 0.05$

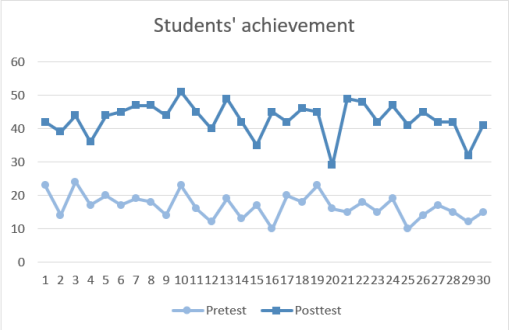

Fig. 5. The students' learning achievement score.

3) The results of student satisfaction with the engineering

design process on web application learning model.

Regarding the study of student satisfaction with the developed learning model, it was found that students were satisfied with the learning model at the highest level ($\bar{x}$ = 4.68, S.D. = 0.56). The top three aspects of satisfaction were 1) convenience to study from anywhere, at any time; 2) convenience to search for information from various sources; and 3) higher learning motivation, respectively.

VI. Discussions

According to the research results, overall the assessment of engineering design process on web application learning model to enhance web programming skills is at the highest level. It may be due to the learning model having an element that promotes web programming skills. The teacher has duties to facilitate students and the student learns through designed activities. Learning activities are designed based on the engineering design process that is synthesized to fit the learner. The learning process consists of 1) define the problem, 2) related information search, 3) develop possible solutions, 4) planning and prototype development, 5) test and evaluation and 6) presentation. These steps were synthesized from relevant research. The main learning steps help learners practice web programming. There is a web application that serves as a learning management system and as learning materials, facilitating learners to learn anywhere, anytime. This is in line with Douglas and Moore *et al.* [19] and Chacharin and Prachya *et al.* [36], who also conducted research on the application of the engineering design process in learning management.

According to the quality of web applications, which was evaluated at a good level. This may be because the web application was developed in accordance with the SDLC process. The developed web application, therefore, is suitable for the learning model. Responsive web design technology was used so the web applications can run on various devices, both desktop and mobile. The web application has the appropriate function as the learning management system and the teaching media. Students can learn through lessons on the web application and can practice writing HTML and CSS programs through the web application immediately. Through a web application, students can conduct learning activities step by step in the engineering design process and submit work and activity results on the web application. This is in line with Jaimez-González and Castillo-Cortes *et al.* [37], who studied the use of web application technology to manage a programming course.

Regarding the assessment of web programming skills, it was found that students' skills after learning are higher than the set criteria of 80%. In the developed learning model, students practiced web development based on the engineering design process. Each step allows them to practice web design and programming using HTML and CSS. The developed programming can be tested on the web application instantly. Students can immediately see the results of their written code and correct it if it is written wrong. Students can practice their web programming skills through web applications at any time, which will help increase their web programming skills. This is in line with Guswara's research [38] and Thongkoo *et al.* [16], which provided web-based instruction and found that students improved web programming skills. As for the achievement assessment, students are found to have higher achievement after learning. It may be because students learned from practicing website development based on the engineering design process and through the exercises on the web application. This is corresponding to Alemdar, *et al.* [39] who organized an engineering design process to promote students' achievement.

In terms of student satisfaction, it is found that students are satisfied with the developed learning model at the highest level. It may be because students can study through the web application anywhere, anytime. Students are more convenient to perform activities based on the engineering design process and they can practice web programming on the web application. The lesson content is easy to understand. There are many web programming examples that range from easy to difficult. Students can access lessons on a variety of devices. It can be accessed as needed. In addition, the developed web application is beautiful, attracting students' learning interest. This is consistent with Chanchalor and Jitjumnong *et al.* [21] and Aljraiwi [15], who studied students' satisfaction with web-based learning.

VII. Conclusion

The research results concluded that 1) the engineering design process on web application learning model has the highest level of appropriateness, because learning activities are designed based on the engineering design process that is synthesized to fit the learner. 2) The quality of the web application used in the engineering design process-based learning model is at a very good level in content and technical aspects, because the web application was developed in accordance with the SDLC process. 3) Students' web programming skills are higher than the set criteria of 80 percent, because the students practiced web development based on the engineering design process. 4) Students' learning achievement after learning is higher than before with a statistical significance level of .05, because the students exercise on the web application and 5) Students are satisfied with the learning model at the highest level, because the developed web application is beautiful, attracting students' learning interest. From the research result, it shows that the web programming skills can be enhance by learning with the developed learning model.

This research will be helpful for teachers to use in teaching and learning to develop web programming skills. And to be a model for developing a teaching and learning model together with web application technology that will serve as a guideline for enhancing other skills in the future.

The limitations of the implementation of the learning model must be prepared in terms of information and communication technology for learners before they learn according to the developed learning model. For further research, the learning model should be used in other subjects and to develop other skills of the students, which are necessary in the future.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Noppadon Phumeechanya conducted the research by designed the learning model and web application, collected the data, wrote the paper; Sumalee Soonthara conducted the research by designed the research instruments, analyzed the data, interpretation of results; all authors had approved the final version.

FUNDING

This research project has been funded under the project to develop teachers' potential for academic positions in the fiscal year 2022, grant number DP_65_07 by Research and Development Institute, Nakhon Pathom Rajabhat University.

ACKNOWLEDGMENTS

This research has been certified by the Subcommittee on Research Ethics in Human, Nakhon Pathom Rajabhat University, certificate number 056/2564. The authors would like to thank Professor Dr. Monchai Tiantong as a consultant for this research.

REFERENCES

[1] E. Fatourou, N. C. Zygouris, T. Loukopoulos, and G. I. Stamoulis, "Teaching concurrent programming concepts using Scratch in primary school: methodology and evaluation," *International Journal of Engineering Pedagogy (iJEP)*, vol. 8, no. 4, pp. 89–105, 2018.

[2] World Economic Forum, The Future of Jobs Report 2020, Geneva, 2020.

[3] Battelle For Kids. (2019). *Framework for 21st Century Learning Definitions.* [Online]. Available: https://static.battelleforkids.org/documents/p21/P21_Framework_DefinitionsBFK.pdf

[4] A. N. Çoklar and A. Akçay, "Evaluating programming self-efficacy in the context of inquiry skills and problem-solving skills: A perspective from teacher education," *World Journal on Educational Technology: Current Issues*, vol. 10, no. 3, pp. 153–164, 2018.

[5] Ministry of Foreign Affairs, Thailand, *Thailand's Voluntary National Review on the Implementation of the 2030 Agenda for Sustainable Development*, Bangkok, 2021.

[6] The Institute for the Promotion of Teaching Science and Technology (IPST). (2017). Basic science curriculum manual high school level science learning group (revised version 2017) according to the basic education core curriculum 2008. [Online]. Available: https://www.scimath.org/ebook-science/item/8415-2-2560-2551

[7] Teach Engineering. (2021). Engineering design process. [Online]. Available: https://www.teachengineering.org/populartopics/designprocess

[8] K. Billiar, J. Hubelbank, T. Oliva, and T. Camesano, "Teaching STEM by design," *Advances in Engineering Education*, vol. 4, no. 1, 2014.

[9] N. R. M. Hafiz and S. K. Ayop, "Engineering design process in STEM education: A systematic Review," *International Journal of Academic Research in Business and Social Sciences*, vol. 9, no. 5, pp. 676–697, 2019.

[10] K. Y. Lin, Y. T. Wu, Y. T. Hsu, and P. J. Williams, "Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking," *International Journal of STEM Education*, vol. 8, pp. 1–15, 2021.

[11] H. J. Han, and K. C. Shim, "Development of an engineering design process-based teaching and learning model for scientifically gifted students at the Science Education Institute for the Gifted in South Korea," *Asia-Pacific Science Education*, vol. 5, no. 1, pp. 1–18, 2019.

[12] M. A. Evans, C. Schnittka, B. D. Jones, and C. B. Brandt, "Studio STEM: A model to enhance integrative STEM literacy through engineering design," *Connecting Science and Engineering Education Practices in Meaningful Ways: Building Bridges*, pp. 107–137, 2016.

[13] L. Mishra, T. Gupta, and A. Shree. "Online teaching-learning in higher education during lockdown period of COVID-19 pandemic," *International Journal of Educational Research Open*, vol. 1, 2020.

[14] Y. T. Lin, and M. Jou, "A web application supported learning environment for enhancing classroom teaching and learning experiences," *Procedia-Social and Behavioral Sciences*, vol. 64, pp. 1–11, 2012.

[15] S. S. Aljraiwi, "The effect of classroom web applications on teaching, learning and academic performance among college of education female students," *Journal of Education and Learning*, vol. 6, no. 2, pp. 132–145, 2017.

[16] K. Thongkoo, P. Panjaburee, and K. Daungcharone, "Integrating inquiry learning and knowledge management into a flipped classroom to improve students' web programming performance in higher education," *Knowledge Management & e-Learning*, vol. 11, no. 3, pp. 304–324, 2019.

[17] College of Engineering. (2021). *The Engineering Design Process.* [Online]. Available: https://www.engr.ncsu.edu/theengineeringplace/educators/

[18] S. A. Wind, M. Alemdar, J. A. Lingle, R. Moore, and A. Asilkalkan, "Exploring student understanding of the engineering design process using distractor analysis," *International Journal of STEM Education*, vol. 6, no. 1, pp. 1–18, 2019.

[19] K. A. Douglas, T. J. Moore, A. C. Johnston and H. E. Merzdorf, "Informed designers? Students' reflections on their engineering design process," *International Journal of Education in Mathematics, Science and Technology (IJEMST)*, vol. 6, no. 4, pp. 443–459, 2018.

[20] Museum of Science Boston. (2017). The engineering design process. EiE. [Online]. Available: https://eie.org/overview/engineering-design-process

[21] S. Chanchalor, K. Jitjumnong, and P. Phooljan, "The effect of feedbacks on web-based learning modules for vocational students," *International Journal of Information and Education Technology*, vol. 9, no. 11, 2019.

[22] U. Cahyana, S. Supatmi, and Y. Rahmawati, "The influence of web-based learning and learning independence toward student's scientific literacy in chemistry course," *International Journal of Instruction*, vol. 12, no. 4, pp. 655–668, 2019.

[23] L. Astuti, Y. Wihardi, and D. Rochintaniawati, "The development of web-based learning using interactive media for science learning on levers in human body topic," *Journal of Science Learning*, vol. 3, no. 2, pp. 89–98, 2020.

[24] C. Y. Huang, "Learning database through developing database web applications," *International Journal of Information and Education Technology*, vol. 9, no. 4, pp. 241–249, 2019.

[25] S. Malik, M. Al-Emran, R. Mathew, R. Tawafak, and G. AlFarsi, "Comparison of e-learning, m-learning and game-based learning in programming education–a gendered analysis," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 15, no. 15, pp. 133–146, 2020.

[26] F. Dağ, "Prepare pre-service teachers to teach computer programming skills at K-12 level: experiences in a course," *Journal of Computers in Education*, vol. 6, no. 2, pp. 277–313, 2019.

[27] F. Lazarinis, C. V. Karachristos, E. C. Stavropoulos, and V. S. Verykios, "A blended learning course for playfully teaching programming concepts to school teachers," *Education and Information Technologies*, vol. 24, no. 2, pp. 1237-1249, 2019.

[28] University of Wisconsin. (2021). *Rubric for Classroom Web Pages.* [Online]. Available: https://www2.uwstout.edu/content/profdev/rubrics/webpagerubric.html

[29] California State University, Sacramento. (2021). *Rubric for Evaluating Sacramento State Web Pages.* [Online]. Available: https://www.csus.edu/indiv/k/kaym/rubric/webpagerubric.html

[30] S. Kareemee. (2017). Using engineering design process to enhance creativity and problem solving skills. *IPST MAGAZINE*. [Online]. *46(209)*, pp 23–27. Available: http://designtechnology.ipst.ac.th/wp-content/uploads/sites/83/2018/10/Mag-209.pdf

[31] Science buddies. (2021). What is the engineering design process? [Online]. Available: https://www.sciencebuddies.org/science-fair-projects/engineering-design-process/engineering-design-process-steps

[32] S. Barjtya, A. Sharma, and U. Rani, "A detailed study of Software Development Life Cycle (SDLC) models," *International Journal of Engineering and Computer Science*, vol. 6, no. 7, pp. 22097–22100, 2017.

[33] S. Paiva and P. Pinheiro, "Responsive web design for smartphones users: A case study of higher education institutions in Portugal," *CAPSI 2020 Proceedings*, vol. 30, 2020.

[34] M. L. H. Khan, A. Setiawan, and I. Kustiawan, "Design and development of a single page and web-based responsive e-learning system for higher education institutions," *INVOTEC*, vol. 15, no. 2, pp. 85–93, 2019.

[35] C. M. Yang, T. H. Liu, Y. Y. Zheng, and H. T. T. Man, "A study on design thinking based creative product design process in a design project," *International Journal of Systematic Innovation*, vol. 5, no. 3, 2019.

[36] L. Chacharin, P. Prachya, and N. Narongrit, "Designing of computational science learning activities by engineering design processes with online simulation to enhance problem-solving abilities for pre-cadet students," *Journal of Education Studies*, vol. 48, no. 2, pp. 56–73, 2020.

[37] C. Jaimez-González and M. Castillo-Cortes, "Web application to support the learning of programming through the graphic visualization of programs," *International Journal of Emerging Technologies in Learning (IJET)*, vol. 15, no 6, pp. 33–49, 2020.

[38] A. M. Guswara and W. Purwanto, "The contribution of Google Classroom application and motivation to the learning outcomes of web programming," *Journal of Education Technology*, vol. 4, no 4, pp. 424–432, 2020.

[39] M. Alemdar, R. A. Moore, J. A. Lingle, J. Rosen, J. Gale, and M. C. Usselman, "The impact of a middle school engineering course on students' academic achievement and non-cognitive skills," *International Journal of Education in Mathematics, Science and Technology*, vol. 6, no 4, pp. 363–380, 2018.

Copyright © 2023 by the authors. This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (CC BY 4.0).