Journal of Education and Educational Research
ISSN: 2957-9465 | Vol. 7, No. 2, 2024

Improving University Second-year Students' Problem-Solving Skills in Computer Science Course (Digital Logic course) through Engineering Design Process in Inner Mongolia

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Abstract: Many researchers regarded that problem solving skill is one of the most important learning outcomes to help students adapt to the learning and working environment (Xiao et al, 2019). Through reading a large number of articles and experimental research, this study finds that currently the development of and research on problem-solving skill in university students who are major in computer science in digital logic course in Inner Mongolia is limited, especially in the context of STEM education. STEM education is currently widely valued in the K12 stage, but the STEM literacy of college students also needs to be paid attention to. There is an important need for developing university students' problem-solving skill systematically and effectively, revealing the importance of this research. In the research field, process of engineering design was designed to developing students' problem-solving skill. In order to have an in-depth understanding of the research questions, mixed methods were adopted. Students were divided into 2 groups: Experimental Group and the Control Group. The participants were 1 teacher and 140 students at university second-year at a university in Inner Mongolia. To collect reliable and valid data, standardized test of problem-solving skill, teacher interview form was designed. Independent T-test was used to analyze the quantitative data.

Keywords: Engineering Design Process; Problem-solving Skills; Digital Logic; Digital Logic Course.

1. Chapter 1 Introduction

1.1. Research Background

Engineering design can help students have a connection between different disciplines which means through engineering design process they can have a better understanding of core disciplinary subject knowledge applying in different areas (Akins et al,2006). Engineering design not only can support students to apply what they learned into real life but also is a is an important aspect in science education (Berland, Steingut & Ko,2014) [1].

The aim of problem-solving skill in science teaching and learning is to solve the practical problems in our daily. And science is considered as a thinking way in solving a problem. Asking and planning steps which contain in EDP can give students impetus to students' problem-solving skills (Syukri, Mohtar & Soewarno, 2018). So, there come to an idea that combine EDP to improve problem-solving skill in STEM context may have obviously improvement which is the main topic in this research [2].

1.2. Statement of Problem

As integrated engineering in science education especially for college students major in computer science and technology related course like digital logic course is a new field and in the context of STEM education there is limited research to exam the efficacy of this statement (National Academy of Engineers & National Research Council 2009).

By doing this research, it can help Inner Mongolia Normal University Second-year Students who are major in computer science and technology to improve their problem-solving skills in digital logic course through EDP which can help them have a better understanding of the relationship between theoretical knowledge and authentic problems in their daily life. And through this process help them to improve their STEM literacy [3].

1.3. Study Overview

There are lots of researcher who use different assessments methods and instruments to collect data and analyze the problem-solving abilities. In the research mixed method were used. Seventy students who attended this study were separated into 2 groups: experimental group and control group. Students learned the digital logical knowledge through EDP in the experimental group. In control group, there was no intervention [4]. Teachers who teach these two classes was invited to attend an interview to find an in-depth factor about how EDP can improve students' problem-solving skill.

1.4. Significance

In this study, EDP is proposed to improve problem solving skill in digital logical course of university second-year students. The effect of EDP is investigated in comparison the with traditional teaching method. Students who attend this research project not only will have a better understanding of digital logic knowledge but also can solve authentic problems use digital logic theory in the practice through EDP: imagine-plan-create-experiment-improve-ask. After these procedures they also cultivate STEM literacy because in the process of solving digital logic related problems they use science knowledge though engineering design process and improve their ability of solving authentic problems.

2. Chapter 2 Literature review

In many university students who are major in computer science and technology they have a compulsory course named digital logic. This course is difficult for students because it consists of two parts: theory and experiment. In order to find

a better way to help students improve problem-solving skill in this course, EDP was chosen as a new learning way in the research in the context of STEM education [5].

2.1. Engineering Design Process and Problem-Solving Skill

Engineering design is an iterative process in which the problem requirement is satisfied. It is also a process to help students make decision combined with many disciplines, such as basic science, mathematics, and engineering, which are applied to achieve the target. The basic elements of the design process include the ask, imagine, plan, create, experiment and improve (Schubert, Jacobitz & Kim,2012). In different situation, the process varies by discipline and project, and this change can also be seen in the existing curriculum methods that support engineering design (Berland, Steingut & Ko, 2014) [6].

2.2. Digital Logical Course

As a basic compulsory course for computer science and technology major, digital logic course is a foundation for the other hardware related course in the course system. The course of digital logic mainly helps students to analyze and design digital logic circuits, which is specifically divided into two main parts: combinational logic and sequential logic (Shanshan & Shiqiang, 2017).

2.3. The Importance of Problem-solving Skill

In students' education, the problem-solving skill is also an important issue to be instilled in students and must be owned by students in learning STEM related subjects (Pardimin& Widodo,2016). Problem-solving skill is essential for a number of reasons. First of all, problem solving is the most basic ability in students' daily life and when students are trained to solve problems, they will be able to make decisions because through training process they know how to gather, analyze information, and be aware of the requirement (Widjajanti,2009). Secondly, in science learning process problem solving is a key step to form concepts, develop ideas because a concept used to solve problems is objectively meaningful [7]. Thirdly, process standards which contain problem-solving is a learning standard to evaluate students' understanding of learning knowledge (Widodo & Ikhwanudin, 2018).

2.4. Engineering Design Process to Develop Problem-solving Skill

Engineering design process method is an activity of setting a way of thinking to solve a practical problem, which requires logical thinking with systematic characteristics. Contextual and constructivist teaching, such as practical work and practical activities, can improve students' problem-solving abilities [8]. Accordingly, this can be implemented through the application of engineering design process in science teaching and learning (Syukri et al, 2018).

2.5. Theoretical Framework: Use of Engineering Design Process in Digital Logical Course to Develop Problem Solving Skill

As shown in Figure 1, It is the whole research framework which contain two elements of STEM (Science and Engineering). Engineering means EDP which is composed of 6 parts: ask, imagine, plan, create, experiment, improve (Sandra,2018). Problem-solving skill can be measured from 4 angles :1) define and analyze an issue.2) develop and implement a strategy to overcome the issue.3) monitor the progress.4) evaluate the result (Beevers et al ,2003). It means that EDP teaching process can be used in Digital logic course to improve students' problem-solving skill. EDP can improve 8 aspects of problem-solving skill through the six-steps in teaching process.

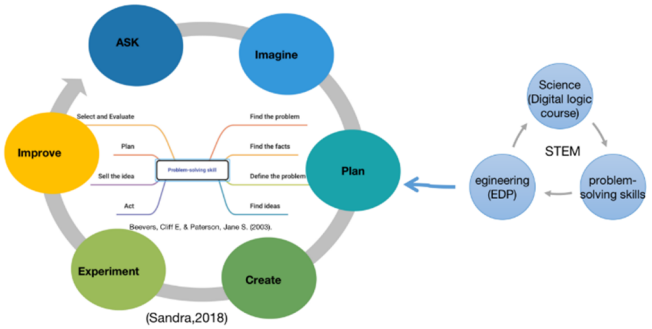

Figure 1. Theoretical framework: Use of STEM activities of scientific investigation to develop problem-solving skill

2.6. Summary

Part 2 give the detailed introduction about the research content and the most important definition and development of the research and why this research is meaningful to do [9].

3. Chapter 3 Methodology

3.1. Mixed Method Design

In this research qualitative and quantitative approaches were utilized in determining the level of problem-solving skills of students. In quantitative approach: pretest and posttest have been designed to test the problem-solving ability of students in digital logical related knowledge [10]. In comparison of the pretest and posttest, it can get a basic information about whether students' problem-solving skill improved or not. After the study, teacher will be invited to attend an interview which find more details about EDP can affect which factors of the problem-solving skill to improve it. Figure 2 shows the overview of method design.

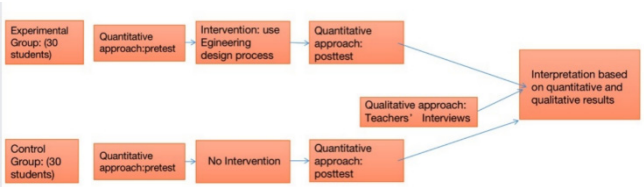

Figure 2. Mixed methods design of quantitative and qualitative approach

3.2. Data Collection and Analysis

The data were collected through pre-test and post-test. The instrument used for the study is the student numerical logic problem solving test, which consists of a total of eight essay questions [11]. This instrument takes the problem-solving ability of digital logic course as the basic index, and develops based on it. The data collected were analyzed by independent T-test, including front/rear measurement, N gain and effect size. Here, a mixed method of independent T-test and pre- test and post-test is used as a tool to explore the effects of multiple learning modes on students' problem-solving ability (Yuliati & Ni'mah,2019).

Table 1. Shows the details about data collection and analysis of this study

Aligned research question	Instrument	Participants and samples	Data collection time	Data analysis method
1. Does engineering design process improve university students' problem-solving skills in Digital logic course?	1. Students' self-assessment of problem-solving skill (Wilson, 1997) 2. Pretest and posttest come from Inner Mongolia Normal University in Digital Logic course (Appendix 2,3)	70 students in experimental group and 70 students in the same school as control group 140 students and 1 teacher in total.	Shortly before and after the entire learning process (pre-tests and post-tests)	1) T-test
2. If so, how does engineering design process improve students' problem-solving skills in Digital logic course?	Teacher's Interview Form (Appendix 4)	Teacher who teaches this course	Shortly after the entire learning process	Coding data

3.3. Triangulation

Triangulation is often used to describe research where two or more methods are used, known as mixed methods. If quantitative and qualitative methods are used to solve a particular problem, the research will get a specific outcome. Figure 3 shows the methods to achieve triangulation. In the research mixed methods was used so the triangulation was used to improve confidence of a proposition using two or more independent measures (Heale & Forbes, 2013) [12].

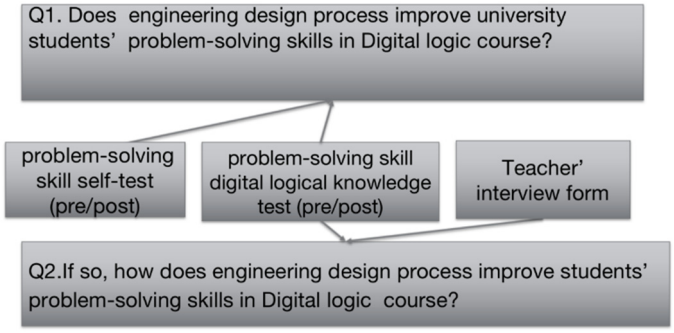

Figure 3. Measures to achieve triangulation in this research

3.4. Curricular Design

To make the improvement of computer science and technology related course in the context of STEM education: 1) To do the digital logical experiment using the EDP to solve the problem to find the most suitable solution; 2) According to each step to make the reasonable task for students; 3) After finishing the whole process to share with each other and find the weakness and advantages of each other to improve own solution [13].

3.4.1. Applying the Theoretical Framework to Design Activities to Develop Problem-solving Skill

In order to improve the students problem-solving skill through EDP in digital logical course. The study has designed the different activities in each step of EDP to enhance the students problem-solving skill from different angle. Table 2 shows the detailed activities of each EDP step [14].

Table 2. The flow of the enriched module

Module phase No.	Key teaching and learning activity	How problem-solving skill are addressed	Learning aim	Aligned stage of the theoretical framework
1	Give students an experimental task and ask them to do it according to the request	To identify the problem requirements.	To investigate the effect on the problem formulation	Asking
2	Students need to have a brainstorm to get the idea from their head to get a solution of the problem	To get a preliminary idea or thought of the solution.	To investigate the effect on the solution planning	Imaging
3	Students who have ideas of solution need to choose a better one to give a detailed design	To get a preliminary solution plan	To investigate the effect on the solution design	Planning
4	Students put the solution plan into use to meet the requirements of the problem.	Put the idea into use to solve the problem.	To investigate the effect on the solution translation	Creating
5	Students use tools or computer to achieve the plan they have created.	Achieve the plan to solve the problem.	To investigate the effect on the solution testing	Experiment
6	In the whole process they can communicate with each other to improve their solution.	Communicate and improve the solution.	To investigate the effect on the solution delivery	Improving

4. Chapter 4 Results and Findings

The purpose of this research is to explore whether the EDP teaching method can improve students' problem-solving ability in computer science courses, and to determine how EDP can play a role in the STEM teaching environment to improve students' problem-solving ability [15].

4.1. Results Analysis

Table 3. analysis of problem-solving skills

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
Find the problem	pre test	72	3.9722	.81745	.09634
	post test	63	4.3095	.68054	.08574
Find the facts	pre test	72	3.6111	.88502	.10430
	post test	63	4.0873	.84500	.10646
define the problem	pre test	72	3.9722	.83028	.09785
	post test	63	4.2302	.76108	.09589
find ideas	pre test	72	3.8403	.86735	.10222
	post test	63	4.2460	.72886	.09183
select and evaluate	pre test	72	3.7847	.85509	.10077
	post test	63	4.2143	.74981	.09447
plan	pre test	72	3.7917	.83813	.09877
	post test	63	4.2460	.72886	.09183
sell the idea	pre test	72	3.7431	.91541	.10788
	post test	63	4.2063	.69928	.08810
act	pre test	72	3.9931	.85783	.10110
	post test	63	4.2698	.68289	.08604

Table 4. T-test analysis of problem-solving skills

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Find the problem	Equal variances assumed	.248	.620	-2.584	133	.011	-.33730	.13055	-.59552	-.07909
	Equal variances not assumed			-2.615	132.688	.010	-.33730	.12897	-.59240	-.08221
Find the facts	Equal variances assumed	.149	.700	-3.185	133	.002	-.47619	.14950	-.77190	-.18048
	Equal variances not assumed			-3.195	131.969	.002	-.47619	.14904	-.77100	-.18138
define the problem	Equal variances assumed	.032	.858	-1.872	133	.063	-.25794	.13780	-.53050	.01463
	Equal variances not assumed			-1.883	132.700	.062	-.25794	.13700	-.52892	.01305
find ideas	Equal variances assumed	.039	.845	-2.919	133	.004	-.40575	.13901	-.68070	-.13080
	Equal variances not assumed			-2.953	132.796	.004	-.40575	.13741	-.67754	-.13396
select and evaluate	Equal variances assumed	.875	.351	-3.083	133	.002	-.42956	.13934	-.70518	-.15395
	Equal variances not assumed			-3.110	132.999	.002	-.42956	.13813	-.70277	-.15635
plan	Equal variances assumed	.604	.438	-3.338	133	.001	-.45437	.13613	-.72362	-.18511
	Equal variances not assumed			-3.369	132.996	.001	-.45437	.13487	-.72112	-.18761
sell the idea	Equal variances assumed	2.825	.095	-3.268	133	.001	-.46329	.14177	-.74370	-.18288
	Equal variances not assumed			-3.326	130.706	.001	-.46329	.13929	-.73884	-.18775
act	Equal variances assumed	.604	.438	-2.054	133	.042	-.27679	.13476	-.54334	-.01023
	Equal variances not assumed			-2.085	131.872	.039	-.27679	.13275	-.53938	-.01419

It can be seen that the results (shows in the table 3 and table 4) of the independent T-test value, the first sig value of the experimental results: Find the problem, Find the fact, the definition of the problem, Find the idea, the selection and evaluation, the plan, the sales idea, and the Act data series are all greater than 0.05, all of the data series conform to the distribution of homogeneity of variance [16]. Based on hypothetical and waiting solutions, there are significant differences in the above-mentioned problems of experimental ability (Because $p<0.05$). Comparison of data before and after the experiment shows that Find the problem (M=3.9722, SD=0.81745), Find the facts (M=3.6111, SD=0.88502), define problems (M=3.9722, SD=0.83028), find ideas (M=3.8403, SD=0.86735), select and evaluation (M=3.7847, SD) = 0.85509), plan (M=3.7917, SD=0.83813), sell the idea (M=3.7431, SD=0.91541), act (M=3.9331, SD=0.85783). The problem is found after the experiment Find the problem(M=4.3095, SD=0.81745), Find the facts (M=4.0873, SD=0.84500), define problems (M=4.2302, SD=0.76108), find ideas (M=4.2460, SD=0.72886), select and evaluate (M=4.2143, SD =0.74981), plan (M=4.2460, SD=0.72886), sell ideas (M=4.2063, SD=0.69928), act (M=4.2698, SD=0.68289) are significantly higher than the average value of the previous experiment, indicating that after experiment, the problem-solving skills of students have been significantly improved. In summary, the application of the EDP teaching method in the digital logic course of computer science can improve students' eight aspects of problem-solving through six steps in teaching process [17].

However, in the digital logic test (full score 20), the average score of the students before class was 10.372, and the average score after one semester of experimental research was 17.842. From the comparison of before and after the average score, it can be seen that the EDP teaching process which used in the digital logic course has effectively improved students' problem-solving skill in the field of professional knowledge. And the t-test data shows that students' problem-solving skill is not only improved in the digital logic courses of computer science, but also improve the ability of applying theoretical knowledge to solve practical problems in daily life [18].

The analysis of interview is showed in follow:

1): The interviewed teachers' views on whether EDP teaching has made any difference in students' problem-solution planning/design/implementation/testing.

A: Let the students be the main part in the teaching process. When eliciting the teaching content, let the students think first, discover the questions and then explain the knowledge content, which will make the professional knowledge can be understood better and the students will have a better grasp of new knowledge. The specific performance is the reaction status of students when teacher asking the random questions in class and the completion of homework after class. Students are often prone to confusion in the process of self-inquiry and problem-solving, because in the previous learning process, teachers have guided them. So, without teacher's guiding they feel confusion when they suddenly flip the classroom to solve problems by themselves. When they don't know where to start the problem, EDP teaching process played a good guiding role to help the students to solve the problem step by step, formulate their own solutions and implement them. The final solutions and test results will be improved step by step based on the teacher's guidance and the sharing of the classmates.

2) The interviewed teachers' views on whether this EDP teaching method will be used in teaching in the future.

A: Yes, because through experiments I found that compared with the traditional teaching mode, the EDP teaching mode can stimulate students' enthusiasm in the learning process and improve their problem-solving skills. EDP also let students learn to explore step by step in this process. The process of discovering the formulation of the plan to the final implementation will make them have a deeper impression of the knowledge they have learned and help them improve their ability to transfer knowledge. In this process, they not only learn theoretical knowledge, but also learn to apply theoretical knowledge to real life practice to solve realistic problems [19].

Through analysis the interview of the teacher, we have clarified in which aspects the EDP teaching method specifically helps students improve their problem-solving skills. The results are analyzed as follows: 1) Compared with the traditional teaching method, the EDP method gives students the ability to discover problems in the ASK part and the opportunity to explore the problems which correspond to the Find and Define parts of the problem-solving skill. In the process of introducing new knowledge and solving new problems, traditional teaching methods often require teachers

as the main body to teach knowledge and assign related problems to students to passively complete homework. 2) In the teaching process of EDP (Imagine, Plan and Create), more attention needs to pay to cultivate students' imagination and creativity. Teachers play an auxiliary role in this process, which is in line with the Find ideas/facts and plan of problem-solving skill. In the traditional process, most teachers assign tasks to students after giving an example which will lead students to answer questions according to the teacher's thinking. In this process, it will cause certain limitations to the students' thinking and will make the students' thinking less actively in the classroom. 3) The teaching method of EDP is divided into two parts in the final assessment part: peer assessment and teacher assessment. Compared with the previous teaching methods, it is directly to evaluate classroom performance and final examination by teachers. In EDP teaching process (Experiment and Improve), there is a process of mutual analysis and discussion. In this process, students will find inspiration from the classmates' sharing and improve their own plan which correspond to Act, Select and evaluate of problem-solving skill [20].

5. Chapter 5 Discussion

The purpose of this research is to study the impact of EDP teaching process on students' problem-solving skill in computer science classrooms, and whether it can improve students' problem-solving skill. In addition, we studied the main factors that teachers of the second-year computer science major of Inner Mongolia area universities have solved in the experimental research of this thesis in the classroom: EDP teaching method, computer course (digital logic logic), problem ability composed of three factors, 16 problems assesses students' professional problem-solving skill from 8 aspects, combined with computer courses and digital logic-related course tests which consists of 7 methods to help determine whether students' problem-solving skill in digital logic course have improved [21].

The descriptive statistics show that EDP has played a positive role in students' learning computer science and improving their problem-solving skill. Using EDP teaching process in computer science classrooms has significantly improved students' problem-solving skill and students' performance in class and their learning attitude are also more active than before. How to improve students' various abilities not only problem-solving skills, but also deeper computational thinking skills, etc. The process of integration with EDP methods in STEM related courses should be the direction of future research. Improving teaching methods and students' interest in STEM learning may be an effective way to promote students' ability [22].

However, many previous studies have shown that in the process of computer science learning, students and teachers did not pay much attention to the integration of engineering design into the curriculum. In particular, the following aspects: quantify requirements; develop systematic methods to choose between possible solutions; or develop mathematical models. These findings are basically consistent with the challenges identified in the existing literature (Crismond & Adams, 2012). We have given an understanding of how these challenges fit together: The analysis shows that the most difficult aspect for students to learn is also to require students to participate in the learning and application of related mathematics, engineering, and science content. Therefore, integrating engineering design into college classrooms will bring certain challenges: the way students participate in engineering design and computer science courses limits their opportunities to apply and explore STEM-related content (Carlson et al.,2018).

5.1. Limitations and Implications

Limitations:

1) The first is the sample that only includes sophomores majoring in Computer Science in Inner Mongolia, so it may not be suitable for research or students in other educational backgrounds [23].
2) During the experiment of this study, it has found that many students lack professional problem-solving skills when they enter the curriculum experimental projects of Undergraduate Computer Science (digital logic) and EDP engineering teaching mode. They use their previous learning and life experience as the basis to learn problem-solving skill. However, in the academic context, only basic ability is not enough. Systematic strategies and heuristics are needed to solve more complex problems (Kimmel et al.,2003).
3) In the previous teaching mode, problem-solving ability has not been paid more attention because it is a relatively abstract skill and it is difficult to evaluate objectively (Woods et al.,2000). Many teachers even lack certain professional evaluation assessments to evaluate it in the teaching process.
4) How engineering can effectively link the students from different majors with other disciplines to improve their problem-solving skill has not been effectively studied, such as combining with computer science, mathematics and geography to develop students' problem-solving skill (Hudson et al., 2013).

Implications:

1) According to the results of this research, teachers should improve their problem-solving skills in STEM computer classrooms during the EDP teaching process, and promote students' learning initiative by piloting new teaching methods (EDP) to promote STEM education and problems. The integration of solving skills enhances the goal of achieving problem-solving skills.
2) Experimental results show that teachers should try to innovate teaching models and use different teaching methods to cultivate students' interest in STEM learning, promote active learning and improve problem-solving skills [24].
3) In future research, we should pay attention to the students' grade differences, gender differences and professional differences. The research object of this paper is the problem-solving skill of sophomores majoring in Computer Science in the EDP teaching context, but the problem-solving skill of students from different grades, genders and even majors may produce different results under the same conditions which we have not taken into consideration in this research.
4) The experiment has found that in the teaching process, most teachers arrange the determined problems in the classroom for students to solve. Students lack the key steps in the problem-solving skill of independent discovery and exploration. In the future teaching, we should carry out more heuristic problem exploration, and let students express or re describe the problems (Stuart, 1997). Because the research of Woods (1979) shows that the ability to define problems and describe what

problems do when solving problems is a powerful symbol of students' problem-solving skill.

6. Chapter 6 Conclusion

It is obviously to see according the results of the research infusing EDP teaching process in the computer science course: digital logic can help students to develop and improve their problem-solving skills. And EDP teaching process can improve eight aspects of it: Find the problems/facts/ideas, define the problem, select and evaluate idea, plan and act through the six-teaching process and each step of process will contain some aspects of them. Therefore, according to the comparison of experimental research data, it has found that the students' problem ability has been significantly improved.

Incorporating EDP into the digital logic course of the university's computer science major, successfully helping the second-year university students to improve their problem-solving skills effectively. The EDP teaching process makes it easier for students to understand and grasp in the process of learning new knowledge and enhances the ability to use the learned knowledge to solve practical problems. And they have learned how to apply theoretical knowledge to solve problems they meet in daily life. In the future course education, not only should the teaching plan be implemented in the digital logic course, but also efficient and innovative teaching methods should be developed in other courses. This will help students learn STEM knowledge comprehensively and improve the problem-solving skill in each course.

More emphasis will be focused on problem-solving in the teaching of computer digital logic courses in the future. This will require a very comprehensive effort by the School of Computer Science, including pre-class assessment of students' initial problem-solving abilities, teachers' mastery of EDP teaching methods, and how to continuously strengthen students' problem-solving throughout digital logic courses. Problem-solving ability is one of the most important students' skills in the 21st century. It is usually considered an important part of the engineering design process, but it is often neglected in the classroom. In the future teaching process, let problem-solving skill run through the entire curriculum is one of the essential keys to teaching. Although the knowledge learned in each discipline requires different solutions, the ability to solve each problem has strong connection between different disciplines. When students work hard to explore and solve the situations and problems presented to them in the course, they can not only develop problem-solving skills but also enhance critical thinking skills or other skills. This article shows how to use the EDP teaching in the digital logic course of computer science to better develop students' problem-solving skills and comprehensive literacy in the application of STEM knowledge.

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