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Innovative STEM-based Teaching of 'Power Transmission Systems' for Electrical Engineering Students

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Abstract

STEM stands for Science, Technology, Engineering and Mathematics. STEM education is an educational method that integrates these fields in an interdisciplinary and hands-on approach, helping students develop critical thinking, problem solving, teamwork and communication skills. STEM education is increasingly asserting its important role in training high-quality human resources to meet the requirements of the 4.0 Industrial Revolution. Implementing the STEM education model at universities is a necessary step to improve training quality and create generations of creative and innovative students. During the process of training students in electrical engineering, in order to achieve high quality and effective training, we boldly researched a new university teaching model: STEM combining experiential pedagogy with the topic of Systems. power transmission system, then guide students to practice operating the power system on the school's practice model. The power transmission system is a complex network of electrical lines, transformer stations and other equipment responsible for transmitting electricity from the place of production (power plant) to the place of consumption (industrial park)… , manufacturing plant, ...). This system plays an important role in ensuring safe, stable and effective electricity supply for all activities of social life.

Keywords: STEM Education, Engineering Design Process, Project-Based Learning, Electricity Transmission, Electrical Engineering.

INTRODUCTION

STEM education is an interdisciplinary approach to teaching in which science, technology, engineering, and mathematics are integrated into a cohesive, application-based learning model (Li et al., 2022a; Li et al., 2022b; Oquendo-Colón et al., 2023). STEM education equips students with 21st century skills such as problem-solving, critical thinking, teamwork, communication, and creativity (Ashraf & Damaj, 2018; Ro, Fernandez, & Ramon, 2022). The goal of STEM education is to equip students with the knowledge and skills needed to succeed in a knowledge- and technology-based global economy (Johnson et al., 2020).

The authors studied and applied the modern educational method of STEM combined with the use of practical experiential teaching methods in guiding STEM project topics in the electrical engineering program. The quantitative assessment method combined with the self-assessment results of students was conducted after the end of the course. The implementation of STEM-oriented learning with the support of practical model equipment significantly improved the problem-solving ability, technical design thinking and learning experience of students in the STEM major. This was achieved under the guidance of lecturers.

In this article, the author studies the teaching topic "Power Transmission System" closely following the program of Electrical Engineering for undergraduate students at at an University in Viet Nam, in line with the current and near future development trends of power transmission

technology in the Electrical Engineering industry in Vietnam. The article outlines the process of designing lectures in the direction of STEM education so that groups of students can experience real equipment, thereby applying basic knowledge to design and manufacture models of power transmission systems, providing electricity for households using electricity. With the aim of helping students understand the principles, structure and power transmission technology of the Power System. From there, students discuss and propose technical processes to design power supply systems for life and production. These skills will help them succeed in their studies and become future engineers.

METHOD

This study used a quasi-experimental design with two groups: an experimental group taught the topic "Power Transmission System" following the STEM education orientation integrating the 6E model, Engineering Design Process (EDP), and Project-Based Learning (PBL); and a control group taught using the traditional method. This design allows to compare the effectiveness of the STEM approach on learning outcomes, engagement, and attitudes of students compared to the current teaching method.

The research subjects were 3rd year students majoring in electrical engineering at an University in Viet Nam. The total number of students participating in the study was 60 students, divided into two groups: an experimental group of 30 students and a control group of 30 students. The experimental group was taught using a modern innovative method following the STEM education orientation integrating the 6E model, Engineering Design Process and Project-Based Learning, in which the stages of 6E were integrated with the steps of EDP and implemented through real projects. In contrast, the control group was taught using the traditional method, mainly based on lecturers' lectures and theoretical exercises. The content and teaching duration of both groups were similar, only differing in the pedagogical approach. Data were collected through knowledge and skills assessment tests conducted before and after the end of the topic in both groups. For the experimental group applying PBL, the project products were also assessed using rubrics based on criteria of professional knowledge, ability to apply EDP and teamwork skills. In addition, a student opinion survey was used to collect feedback on the learning experience with the new method. Quantitative data from the test will be analyzed using SPSS statistical software to compare the mean scores between the two groups. Qualitative data from the survey and comments in the project report will be analyzed using content analysis to identify key themes and trends, deepening the understanding of student performance and experience.

RESULTS AND DISCUSSION

Integrating STEM in Higher Education

Universities are tasked with addressing the needs and demands of the future workplace, including technical skills, transferable skills such as collaboration, communication, creative and critical thinking. For this reason, the trends that universities are taking into account when redesigning their curricula aim to create broader, system-wide changes in higher education. The driving force behind the need to integrate STEM to address local and global issues: resource use, carbon emissions (Conner, 2021). STEM education, with its interdisciplinary approach and focus on practical application, has been shown to have a positive impact on increasing interest and motivation to study in STEM fields, developing problem-solving skills, scientific competence, and learning outcomes of learners. The positive impacts of STEM education on learners are specifically demonstrated as follows: Arousing passion for discovery and curiosity through practical experiences, project-based learning activities, experiments and practices (Li et al., 2021); Connecting knowledge with reality helps learners understand the meaning and importance of learning, making them more interested and motivated to learn (Li et al., 2021; Triplett, 2023); Developing skills and abilities to help learners become more confident, more motivated to learn and achieve success (Bunnell et al., 2023; Dewi & Mashami, 2019); Creating an interactive, dynamic learning environment helps increase learners' interest, concentration, and retention (Bunnell et al., 2023; Dewi & Mashami, 2019; Triplett, 2023); Career guidance supports learners to have early access to careers related to science, technology, engineering, and mathematics, thereby helping them identify their interests, abilities, and career orientation (Burack et al, 2019).

STEM topic: “Power transmission system” in the course Power supply system design, Electrical Engineering major

STEM education is a purposeful educational activity, so identifying STEM topics to convey knowledge is very important. In essence, taking "products" as the starting point for learners' cognitive activities and the criteria of "products" will be the "cover" for the knowledge and messages that lecturers want students to apply and acquire after completing the task/solving the problem (Bunnell et al., 2023).

The course "Power System Design" provides students with essential knowledge and skills related to the design and analysis of power systems, from basic components to complex power networks. According to (Weedy et al., 2012), the course introduces the fundamentals of electrical theory, circuit analysis, load management, and smart grid development. Students

will practice through simulation design exercises, helping them better understand the challenges in optimizing the performance, reliability, and sustainability of power systems. In addition, the course also emphasizes the role of technology in developing renewable energy solutions and efficient energy resource management. Through this, students will be equipped with the necessary skills to meet the growing demands of the power industry in the current context of sustainable development.

Choosing a STEM topic is an important step to ensure that the designed product is consistent with the objectives and content of the program. Ensuring feasibility as well as future career orientation of students. Researching educational content is to learn about the objectives and knowledge content of the subjects in the undergraduate Electrical Engineering program in the STEM field (Ju & Zhu, 2023). Group of students went to experiment on power transmission and distribution system can be seen in Figure 1.

Figure 1. Group of students went to experiment on power transmission and distribution system

STEM Topic: “Power Transmission System” is an essential part of the national power grid, delivering electrical energy from power plants to households and businesses. Power Transmission System is an interesting and rewarding STEM topic that arouses students’ passion for science and engineering. By participating in STEM-related experiential and hands-on activities related to power transmission system, students develop critical thinking, problem-solving, collaboration and communication skills, and understand the importance of power grid systems to modern life.

Designing teaching organization process according to STEM education orientation

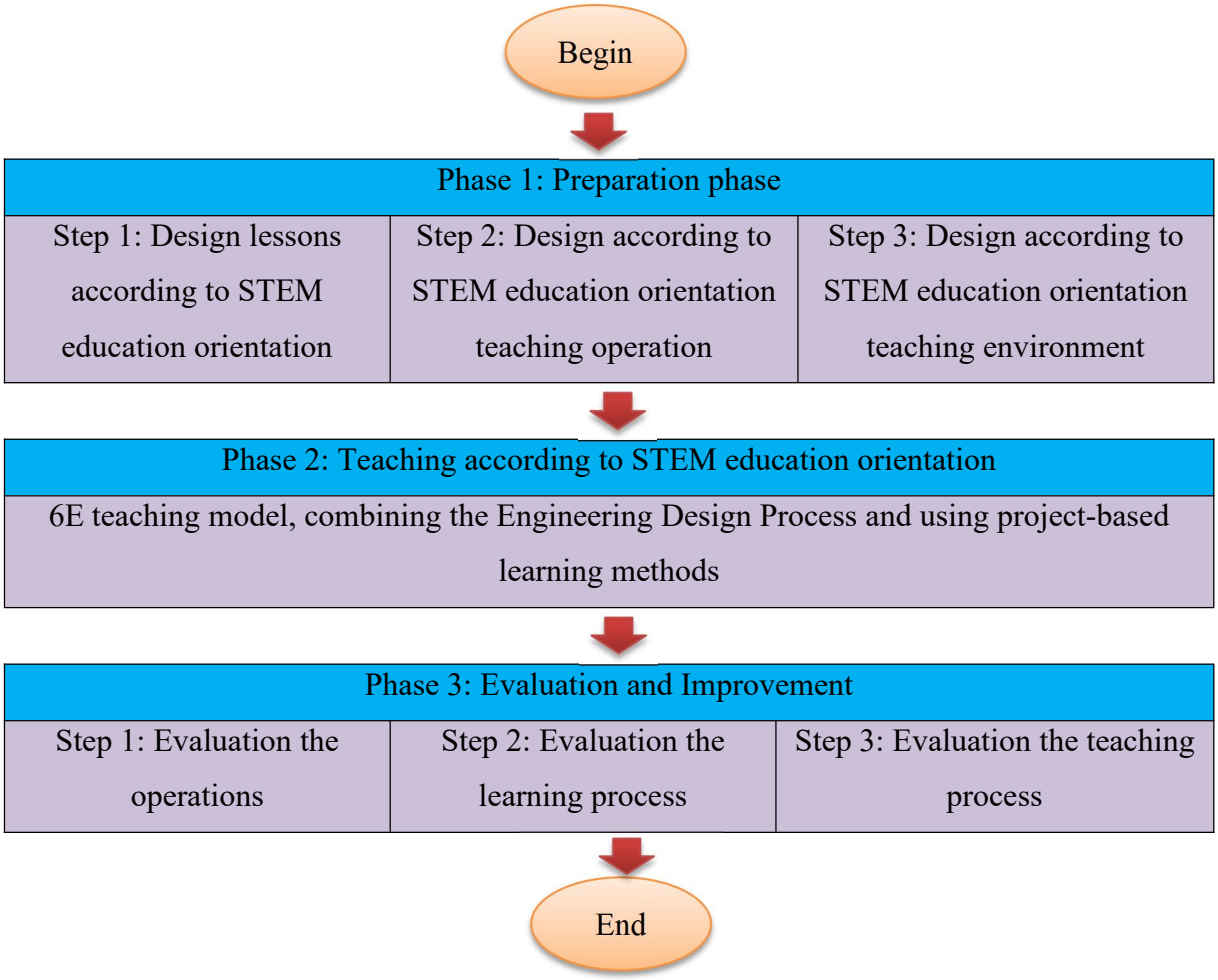


Figure 2. The process of organizing virtual interactive teaching.

In Figure 2, the teaching organization process includes three phases as follows:

Phase 1: is preparation phase to develop an effective according to STEM education orientation interactive classroom organizational structure in which: During the preparation stage, three steps need to be carried out. Step 1: design topics STEM and according to STEM education orientation teaching. Step 2: design according to STEM education orientation teaching activities. Step 3: design the according to STEM education orientation teaching environment..

Phase 2: is according to STEM education orientation teaching based on phase 1. However, this phase is heavily influenced by the intuition of teachers and learners. And is objectively affected by the virtual interaction device interaction with the experimental To achieve high efficiency in implementing STEM-oriented teaching, it is necessary to combine different teaching models and methods. In which, the 6E model, engineering design process and project-based learning method play an important role, complementing each other, creating an experiential and creative learning process. Thereby, students not only acquire

knowledge but also practice important skills such as: problem solving, engineering design, critical thinking, creativity, ...

Phase 3: is the evaluation and improvement. The evaluation and improvement phase are applied to teaching and learning activities according to the following steps. Step 1: evaluate teaching and learning activities. Step 2: evaluate the learning process. Step 3: evaluate teaching methods. During this stage, qualitative and quantitative assessment methods are used based on students' learning results after the experiment, collecting students' opinions after studying the experiment, and getting expert opinions.

6E teaching model, combining the Engineering Design Process and using project-based learning methods to teach the topic "Power Transmission System" for undergraduate students majoring in Electrical Engineering

The study was conducted during the teaching of the Power Supply System Design course - Electrical Engineering major at at an University in Viet Nam. The K11.KTĐ model class consisted of 30 students, under the guidance of specialized lecturers including: Hoang Vu Van, Hai Doan Van. In addition, there were experienced education experts and lecturers with pedagogical qualifications participating and contributing ideas.

- Topic objectives:

+ Knowledge: Students can explain basic concepts of power transmission systems, including: Power sources, transmission capacity, power loss, transformers, power lines, electrical loads, ...; Students can describe the diagram of the power transmission system from the power plant to the point of consumption; Students can state the role and importance of the power transmission system for modern life.

+ Skills: Students apply knowledge of science, engineering and mathematics to solve problems related to the power transmission system; Students work effectively in groups, cooperate and share ideas during the learning process; Students communicate clearly, concisely and present research results effectively.

+ Attitude: Students are interested in learning about science, engineering and power transmission systems; Students have a sense of responsibility in using electricity economically and effectively; Students believe in their own abilities and have a passion for STEM.

- Teaching methods:

+ Learning through practical experience: students participate in practical activities, experiments and tours to directly experience the operation of the power transmission system.

For example: visiting power plants, transformer stations, or conducting experiments to measure voltage and current on power lines.

+ Learning through practice: is an effective learning method, helping students transform theoretical knowledge into practical skills. Through practice, students will gain a deeper understanding of concepts, practice critical thinking and improve problem-solving skills.

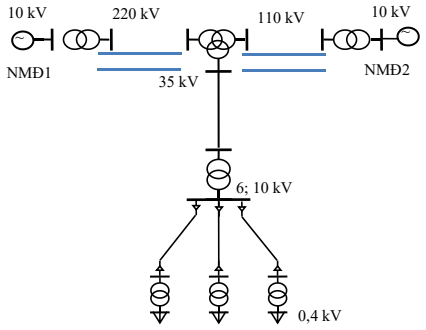
+ Group learning: students work in groups to complete learning tasks, discuss and share ideas with each other. Group learning activities help students develop effective communication, cooperation and teamwork skills.

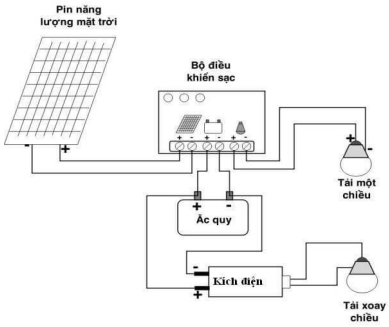
- STEM-oriented teaching activities on the topic: "Electricity transmission system" can be seen in Table 1.

Table 1. STEM-oriented teaching activities on the topic: "Electricity transmission system"

Procedure	Objectives – Teaching content	Teaching – Learning Activities	Time
Phase Engage	- Arouse students' curiosity and interest in the power transmission system. - Help students realize the importance of electricity in daily life. - Lay a foundation of basic knowledge about electricity so that students can easily absorb the following knowledge.	- The lecturer creates real-life situations (showing students a simulation of an electric circuit) to attract students' attention and pose problems to be solved. - Open discussion: the lecturer asks open-ended questions to stimulate students' thinking: Where does electricity come from?; How is electricity transmitted?; Why does the light turn on when the switch is turned on?	8 minutes
Phase Explore	- Objectives: + Expand knowledge: Help students gain a deeper understanding of concepts related to the power transmission system. + Encourage curiosity: Ask questions and create opportunities for students to find answers themselves. + Develop research skills: Train students in information collection and analysis skills. - Suggested questions to stimulate thinking: + How is electricity transmitted? + Why use transformers in the	- Explore the power transmission system model: a simple model of the power transmission system including power plants, transmission lines, transformer stations and consumers. Power transmission system practice panel can be seen in Figure 3.  Figure 3. Power transmission system practice panel	22 minutes

	power transmission system? + What factors affect power loss on the line? + What methods are there to minimize power loss? + What are the challenges in building and operating the power transmission system?	- Discussion: Ask students about the role of each component in the system. - Ask students to learn about types of power plants, operating principles of transformers, issues related to power transmission. - Ask suggestive questions to stimulate students' thinking. - Divide the class into 4 small groups. Each group will research a different aspect of the power transmission system (Power plant; Power grid; Transformer station; Electrical load) and present to the class.	
Phase Explain	- Objectives: + Synthesize knowledge: Provide students with an overview and system of the power transmission system. + Explain concepts: Clearly explain complex concepts in a simple, easy-to-understand way. + Connect knowledge: Link knowledge learned in previous stages to create a complete picture. - Teaching content: + Origin of electricity: Types of power plants (hydroelectric, thermal, wind, solar...). + Electricity production process: Converting primary energy into electricity. + Power transmission system: Main components, functions of each component. + Transformer operating principle: Increasing voltage, decreasing voltage. + Power loss and how to reduce it: Joule-Lenz effect, using large cross-section wires, increasing	- Presentation of knowledge: + Illustrative diagram showing the structure and operation of the power transmission system. Dong Nien 110kV power transmission station can be seen in Figure 4.  Figure 4. Dong Nien 110kV power transmission station + Clearly explain the role of each component: power plant, transmission line, transformer station, distribution station. - Explain important concepts: + Voltage, current intensity, power: Explain the meaning of these quantities and the relationship between them. + Transformer: Explain the operating principle of the transformer and its role in power transmission.	25 minutes

	voltage. + Electrical safety: Measures to ensure safety when working with electricity.	+ Power loss: Explain the causes of power loss on the transmission line and measures to reduce it. - Discuss and answer questions: + Questions: Ask questions to stimulate students to think and discuss. + Answer: Answer all students' questions. - Exercises: Let students do simple calculation exercises related to power.	
Phase Elaborate	- Objectives: + Applying knowledge: Giving students the opportunity to apply the knowledge they have learned to real-life situations. + Developing skills: Practicing problem-solving, teamwork and creativity. + Expanding thinking: Encouraging students to think about more complex issues related to the power transmission system. - Design of schematic diagram of power transmission system (see Figure 5).  Figure 5. Structure of the Electrical System, Power Transmission - Small project related to the power transmission system: Design a solar power system for your home; Propose solutions to reduce environmental pollution during the power generation process.	- Ask students to design and build a miniature model of the power transmission system, using simple materials such as wires, light bulbs, batteries, transformers (if any). - Assess students' ability to work in groups, problem-solving ability and creativity. - Solve practical problems: Situations: Set up practical situations such as: Why are street lights often installed in high positions? Why do lights in houses often flicker when there is an electrical fault? How to reduce electricity loss in the home? - Discussion: Let students discuss and propose solutions to these problems. - Assign student groups a project topic related to the power transmission system. Ask groups to present the project results to the class.	35 minutes

Phase Engineer	- Objectives: - Apply knowledge: Students apply the knowledge they have learned to design and build a simple power transmission system. - Develop skills: Practice design, construction, problem solving and teamwork skills. - Stimulate creativity: Encourage students to come up with creative and unique ideas during the design process. - Design content: + Schematic diagram of a household solar power transmission system(see Figure 6).  Figure 6. Principle of Household Solar Power System + Model of manufacturing household solar power products (see Figure 7)  Figure 7. Demo of a household solar power system designed and manufactured by students	- Problem statement: Topic: Set a specific problem, "Design a power supply system for a small village without a national grid". Requirements: Ask students to identify the necessary elements for the system (energy source, converter, transmission line, consumption equipment...) and the conditions that need to be met (efficiency, cost, safety). - Plan: Divide the class into 4 small groups. Each group will make a detailed plan, including: Select a suitable energy source (solar, wind, water...); Select necessary equipment; Draw a circuit diagram; Estimate costs. - Design and construction: + Search for documents: Search for information about electrical equipment, circuits, and how to calculate capacity. + Construction: Use available materials and simple tools to build a system model. + Testing and Adjustment: Check if the system is working properly, meeting the initial requirements; Adjust the design if necessary. - Presentation and Defense: + Report: Each group will prepare a report presenting the design, construction process and results achieved. + Comments: Other groups and the lecturer will give their comments.	120 minutes
Phase Evaluate	- Objectives: + Assess the learning process: Assess the level of achievement of	- Self-assessment: Each student will self-assess their work process, the difficulties they encountered and	15 minutes

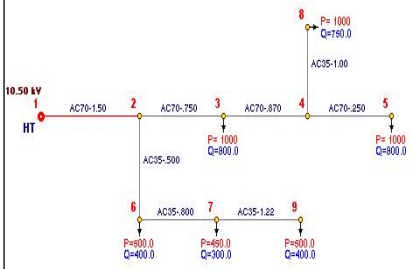
	the goals set in the previous stages. + Identify strengths and weaknesses: Identify what students have done well and what needs improvement. + Provide feedback: Provide students with specific feedback to help them improve. + Adjust the teaching process: Adjust teaching methods to suit the needs of students. - Applied exercises: Use LOADFLOW software to check the load of the grid (see Figure 8).  Figure 8. LOADFLOW software Set up the diagram this and record the results in the boxes below: 1. Is the grid overloaded (tick the box you choose). Is the grid not overloaded? Is the grid overloaded? 2. Maximum load ratio of the line (write the maximum load ratio % of the line section in the box).	what they have learned. Lessons learned: Students will draw their own lessons. - Peer assessment: Students assess the work process and results achieved by group members. Providing feedback: Students give comments and suggestions to help each other improve. - Lecturer assessment: + Observation: Lecturers observe students' work process throughout the project implementation process. + Product assessment: Lecturers evaluate the final product of each group. + Feedback: Lecturers provide detailed feedback on the strengths and weaknesses of each group and individual. - Application exercises: Have students do application exercises to test their ability to apply knowledge to practice.	

Figure 9. STEM activity on the topic of Power Transmission System

Figure 9 shows a sample STEM lesson on the topic of Power Transmission System, where the lecturer presents an overview of the power transmission system in the electrical engineering laboratory. Students are divided into groups to study, research and give scientific insights into this system.

After the specialized lesson: "Power transmission system" taught according to STEM education orientation, qualitative evaluation results were collected from the opinions and comments of the lecturers who participated in observing the lesson. After the end of the lesson, the author received quantitative results of the evaluation scores in the experimental class (see Table 2, Table 3, Table 4). Processing experimental results: Mathematical statistics data collected during the experiment were processed using SPSS and Microsoft Excel software.

Based on the feedback received after participating in the STEM course teaching the specialized topic "Power transmission system", the authors drew the following conclusions: Introducing STEM education orientation into teaching increases students' interest in learning; Interesting lectures; A significant number of students are active and enthusiastic in learning during the lesson development process; Students' professional practice skills are clearly demonstrated.

Students are able to participate in self-study activities and actively experience STEM practice. The class becomes natural and fun. The relationship between teacher and student is enhanced because teachers can easily see the cognitive development and learning aptitude of each student. Conversely, proficient students have the opportunity to demonstrate their deep practical expertise.

Table 2. Score ranking

Point conversion table				
A	B	C	D	F
8.5-10	7.0-8.4	6.0-6.9	5.0-5.9	<= 4.9

Table 3. General learning scores

Content	How to calculate general study score
1. Learning process points	Learning process score = (Test score 1 + Test score 2)/ 3
2. Final learning score	Final score = 30% of learning process + 70% of final exam score

To improve and demonstrate the improvement and effectiveness of the topic: "Power transmission system" according to STEM education orientation, the author continuously conducts quantitative evaluation of the mid-term score of the learning process (LPS) and the course completion score (CCS) of the experimental class (EC) to find the difference in Table 4 and Figure 10.

Table 4. Midterm score of the learning process (LPS) and course completion score (CCS)

Score Classification		EC	
		LPS	CCS
A	8.5-10	4	9
B	7.0-8.4	17	19
C	6.0-6.9	9	2
D	5.0-5.9	0	0
F	<= 4.9	0	0

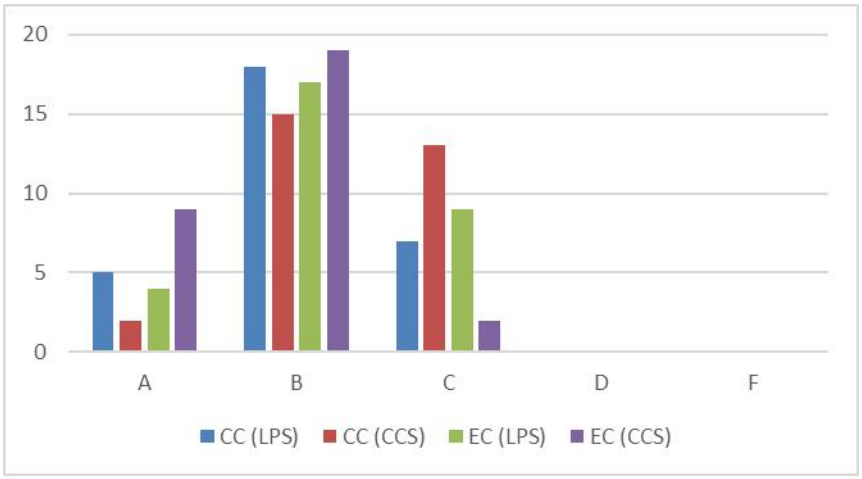


Figure 10. Score Distribution Chart of Control class (CC) and Experimental Class (EC)

In addition, to evaluate the effectiveness of the selected methods for the subject under study, in addition to conducting the above pedagogical experiments, the research team also used another research method of collecting students' opinions after class to assess student satisfaction, skill development, and students' self-study ability. Learning skills, teamwork skills. At the same time, the researchers used expert evaluation to confirm the effectiveness of the teaching method according to the STEM education orientation.

Table 5. Sample assessment of student satisfaction after studying the topic

After completing the topic: "Power transmission system" taught according to STEM education orientation	1. Interest	2. Attractive	3. Intuitive	4. Vivid	5. Easy to understand
Totally agree	30	27	30	26	27
Agree	0	2	0	3	3
Partially agree	0	1	0	1	0
Disagree	0	0	0	0	0
Totally disagree	0	0	0	0	0

After finishing the lesson, based on Table 5, the surveyed students felt 100% interested, the lecture was 85% interesting, the lecture was easy to understand 85%, the lecture was 100% intuitive, the lecture was lively 80%,

Teaching the Power Transmission System according to the STEM education orientation, under the supervision of the instructor, has significantly improved the problem-solving skills and learning experience of engineering and technology students. technology, thereby creating favorable conditions to achieve the prescribed implementation standards. Evaluating the effectiveness of applying the STEM education orientation in teaching the Power Transmission System, experts' opinions said that 83.3% of opinions said that it increased the ability to work in groups, 83.4% of opinions agreed. Increased problem solving ability, 85% of opinions said that it would increase thinking ability, 83.3% of opinions said that it would increase knowledge absorption ability, 80% of opinions said that it would increase concentration ability, 79.9% of opinions said that self-study ability would increase. More confidence in professional practice, 83.4% of opinions increased interaction with lecturers, 90% of opinions increased interaction with practice equipment. Through the expert's evaluation results, it is possible to initially evaluate the effectiveness of STEM classes on the lesson.

CONCLUSION

Teaching the topic “Electrical Transmission System” following the STEM education approach not only enables Electrical Engineering students to master specialized knowledge but also fosters creative thinking, problem-solving, and teamwork skills. By integrating theory with practice, employing active learning methods, and leveraging modern technology, the

teaching program has sparked students' interest and proactiveness in learning. As a result, students not only gain a deeper understanding of electrical transmission systems but are also equipped with interdisciplinary thinking, ready to meet the demands of the modern electrical industry. The STEM approach in teaching this topic marks a significant step forward, contributing to improving the quality of education and preparing a high-quality workforce for the future.

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