Development of a Science, Technology, Engineering, and Mathematics Curriculum for High School Students Using a Baseline Structure of Renewable Energy

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Abstract

This work aims to study alternative energy using a learning and teaching curriculum to achieve outcomes for student projects. Development of a science, technology, engineering, and mathematics curriculum for high school students was done using a renewable energy baseline structure. The satisfaction of those who completed this curriculum is examined. Learners can use the opportunity to apply their knowledge and skills to further their academic careers at the university level or incorporate them into their daily lives, as renewable energy is of great importance to the nation and students. Twenty-five participants were selected using purposive random sampling. They were students and teachers of science, mathematics, and technology. The research involved analysis of the existing curricula and defining the objectives of sample groups. Content that aligns with the study objectives was developed, focusing on creating alternative energy projects. The designed curriculum is divided into four learning units, solar energy, wind energy, and hydropower, as well as a section on biomass and biogas. The curriculum was evaluated by ten experts and found highly suitable. Teaching effectiveness with a sample group of high school students revealed an effectiveness score of 80.10/83.00, which is higher than the established criterion, 80/80 (pre-test/post-test scores). Pre- and post-testing of the student group revealed that post-learning was significantly higher than the pre-learning results at a statistical significance of α=.05. Additionally, there was high satisfaction with the curriculum, consistent with the research hypothesis.

Keywords: curriculum development, baseline education structure, renewable energy, high school students

1. Introduction

Thailand has consistently achieved advancements in science and technology. Development of essential 21st-century education skills (Chaurasia, et al., 2018) necessitates educational management that enables learners to cultivate thinking, communication, technology utilization, and social development. The education system must integrate these skills into curricula so that learners can apply their knowledge in daily life to achieve their goals. Simultaneously, instructors should employ correct teaching and learning processes, emphasizing hands-on practice by planning and designing appropriate learning experiences.

Energy plays a crucial role in the economy and daily life. Thailand imports much of its energy from foreign countries. Most of Thailand's electricity production relies on natural gas as fuel, and the demand for energy production remains relatively high (Jai-On & Bangtho, 2022). As a result, there will be a continuing need to purchase energy from neighboring countries. For this reason, the Ministry of Energy has been developing knowledge and providing education to the public, youth, and students to support the Kingdom's energy security (Chunphun, Romae, & Hayamin, 2022). Renewable energy is one of the target energy resources expected to reduce natural gas demand for electricity production. When renewable energy technologies become more cost-effective and widely accepted, they can be developed into primary energy sources for electricity generation. Biomass accounts for the largest share of renewable energy-specific power generation, 70.3%, followed by solar energy at 13.5%, biogas and biomass at 6.9%, wind energy at 4.0%, small hydropower at 3.8%, and waste energy at 1.5% (Soranee & Chutima, 2023). Thailand has much potential for solar development, with an average solar radiation intensity of approximately 18.2

mJ·m^{-2}·day^{-1} or about 5 kWhr·m^{-2}·day^{-1}, ranking the country as the 5th most favorable location for solar energy globally (Kulnida & Aumporn, 2019). Renewable energy-based power generation systems will continue to develop in the future. Therefore, it is necessary to educate high school students about this technology, as they choose their careers. Students can make innovations that generate value for themselves, their schools, provinces, and Thailand.

Secondary education is a part of basic education. Its objective is to enhance knowledge and skills in subject-specific areas and to prepare students for higher education. Secondary education is compulsory, so students must complete lower secondary education to fulfill their compulsory education requirements (Tagaew Aekgaraj, 2024). There are two systems for education. The first is high school, which is a continuation of upper secondary education, while high school vocational education teaches various subjects such as industrial crafts and agriculture. Learning management at the secondary level is crucial as it sets the stage for students to make educational choices. Students with a good foundation of knowledge will have more options for further study (Korawit, 2023). There are specific topics related to energy in the science learning management plan for secondary education. In Grade 7, the topics include force, motion, and thermal energy. During Grade 8, students learn about light and its properties. In Grade 9, the subjects include electricity and electronics, mechanical energy, forces, and moments of force. Students must learn about the impending energy crisis, as well as how to utilize energy for maximum benefit as well as understand the advantages and disadvantages of different energy production methods. It is necessary to provide students with a thorough understanding of energy and promote their analytical thinking to make informed choices and develop problem-solving abilities. For these reasons, a training curriculum was developed that integrates basic knowledge with specific information about renewable energy, emphasizing problem-solving in daily life, conservation of the country's energy resources, and striving for the nation’s energy security. Current classroom teaching and learning challenges include a lack of student understanding of their lessons, rote memorization for exams, and non-retention of previously learned material. Students do not understand that their lessons can be applied in real life, resulting in their inability to integrate knowledge into their experiences (Thanapat & Jakkrit, 2024). They cannot solve problems and do not understand the principles and relationships of the lesson content. Additionally, they lack computational capability and the ability to link and apply scientific concepts learned (Dey, 2024). The current research found that the problems in implementing science teaching and learning processes in schools include a shortage of personnel, teachers having excessive workloads, frequent teacher transfers, as well as a lack of laboratory equipment and books. The problems in the science teaching and learning processes that need to be addressed are finding ways to analyze the basic knowledge and abilities of learners, allowing learners to explore natural learning resources, materials, equipment, and facilities that teachers will use, and applying knowledge from the learning process in project work. In Thailand's Basic Education Core Curriculum BE 2551 (CE 2008), specific subject content such as science, technology, and mathematics are emphasized. However, there is a lack of integrated learning content. An engineering design curriculum is needed to integrate the disciplines and content to develop learning objectives and projects (Sudarat, 2024). However, in the development of an effective training curriculum for teachers and students, specific components are required including the curriculum, administration, planning, implementation training, instructor training, trainees, training staff, and environment. This requires that the researchers develop a necessary curriculum that will inform teachers and students of the importance of renewable energy projects and the application of knowledge to further develop the nation.

2. Literature Review

High school students have benefited from the development of training courses in the past (Chalida Joongpan & Yada Atanan, 2024). Development and assessment of a training program on drought response was done for a sample of secondary school students. The examination of appropriateness yielded results at the highest level ($\bar{x}$=4.83, S.D.=0.02). The course comprises concepts and rationale, objectives, content, structure, instructions for structuring learning activities, utilization of media and learning resources, as well as assessment and evaluation methods. The curriculum prioritizes the student, offering opportunities for experiential learning in real-world situations. All proposed learning exercises are intuitive, pragmatic, and have real-world applicability. Participants engage in the process. It was concluded that local academics and communities should use their educational resources to effect change and enhance understanding of drought response in educational institutions and communities (Dumulescu, et al., 2021). Aligning with the national economic and social development plan, we prioritized human development, formulated a curriculum for student leadership training, subjected it to expert review and evaluation, tested its implementation, and applied a modular framework for the curriculum. The findings indicated that, at the α=0.05 level, student leadership behaviors enhanced post-training relative to pre-training levels. The research determined that various educational levels, such as primary and secondary, ought to implement distinct curricula to address the interests and developmental phases of their respective student populations (Erevelles, et al., 2016; Pichaya & Wisud, 2021). This study examined the impact of the STEM education framework and project-based learning management on the academic performance and creativity of Prathom Six students in science disciplines. At the α=.05 level, academic achievement was significantly higher after learning than it was before learning. The indicators show that students acquired knowledge and applied it by participating in project activities and producing work samples, all while adhering to the principles of STEM education. We recommend that educators incorporate information that is consistent with learning standards and indicators into the learning management plan.

3. Research Objectives

The primary objective of the current study is to develop a curriculum in science, technology, engineering, and mathematics for high school students. This will involve energy projects and employ a satisfaction survey of those who have completed training in a curriculum development program.

4. Research Hypothesis

The science, technology, engineering, and mathematics curricula for high school students, as well as developed energy projects, meet a specified criterion of 80/80.

5. Research Methodology

This research developed a training curriculum for high school students in science, technology, engineering, and mathematics using renewable energy project-based learning. It employs an integrated model of the knowledge disciplines that the learners studied and applies it to high school students for teaching and learning management, allowing learners to integrate knowledge across subject groups. The research framework, shown in Figure 1, consists of a curriculum development process, learning units, project-based training methods, and evaluation of integrated lessons across subject groups through the development of renewable energy projects, learners' academic achievement, learner satisfaction, and teacher satisfaction.

5.1 Research Preparation

Research preparation includes studying the problems of teaching and learning management, relevant curriculum data, planning project implementation, selecting the research area, and coordinating with stakeholders.

5.2 Analysis of Course Curriculum

From a survey of teaching and learning management related to the training curriculum, the researchers analyzed the basic education core curriculum at the secondary level to obtain learning units, topics, and behavioral objectives, considering their alignment with the basic education core curriculum.

5.3 Development of Research Instruments

Training curriculum development was done by forming a learning management process that integrates content from various disciplines based on renewable energy projects. The content in the integrated learning instructional package consists of 1) an instructional package on renewable energy project-based construction for high school students, and 2) teacher's and learner's manuals. Instructional packages, teacher guides, and student workbooks facilitate effective assessment and evaluation. Instructors can measure and evaluate student learning outcomes, leading to enhanced learning management. Students can effectively grasp the content, acquire skills, and apply their knowledge in real-world settings.

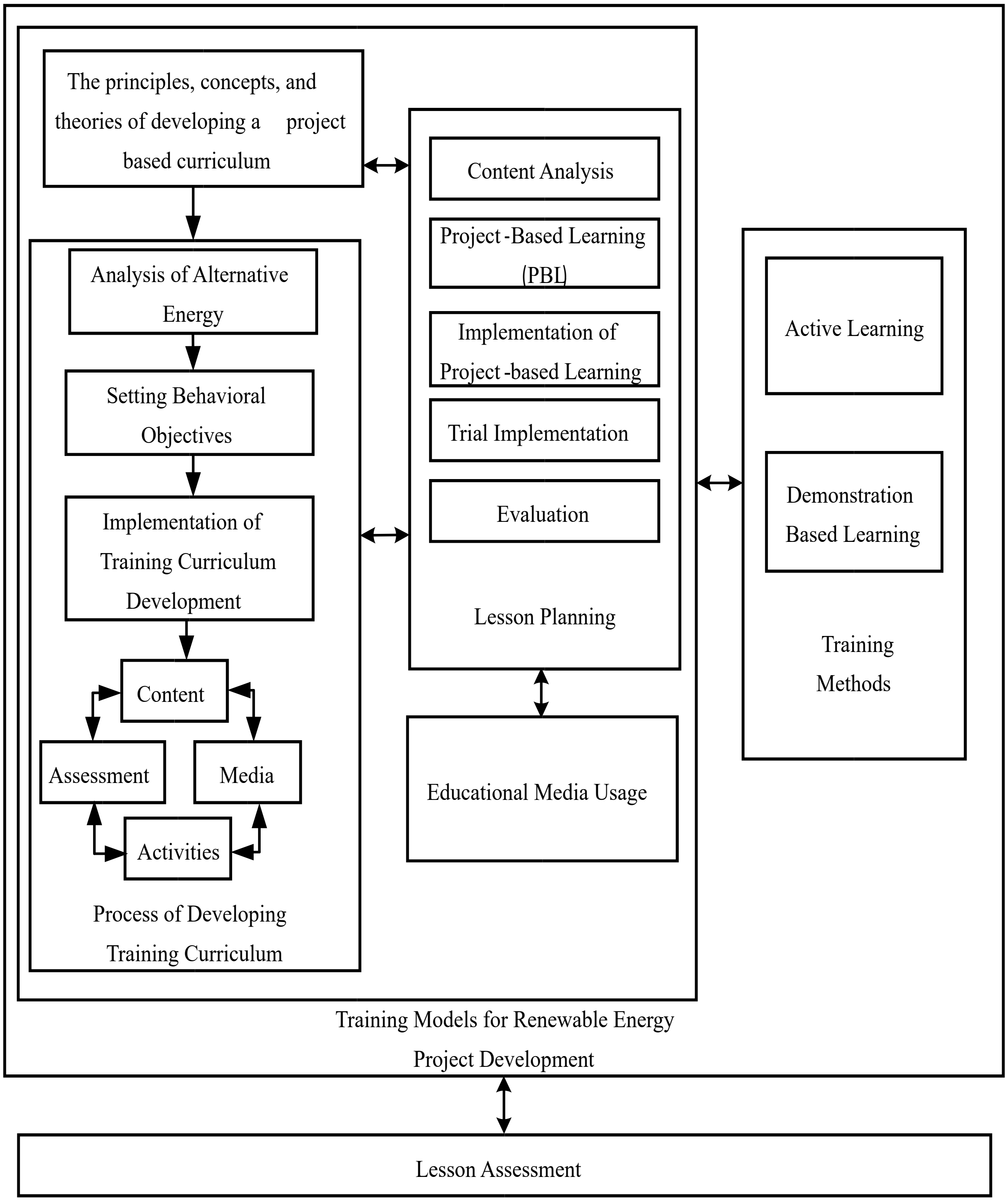

Figure 1. Diagram of the Conceptual Framework

5.4 Evaluation by Experts

The researchers divided the evaluation format into two parts, content evaluation, and instructional media evaluation. These were determined by the difficulty level of the exam questions. Expert evaluation to provide recommendations for revising, developing, and improving the content, teaching materials, and exams to ensure accuracy, consistency with objectives, and the ability to accurately, fairly, and reliably measure learners' knowledge and skills. The process is as follows.

5.4.1 Content evaluation

Analyze the appropriateness of the content for teaching the curriculum training package in science, technology, engineering, and mathematics using renewable energy project-based investigation for high school students. Evaluation results by experts regarding the consistency of the content with the objectives are shown in Table 1. The Index of Congruence (IOC) refers to a rating scale used to assess how well an item (such as a specific task or experience) aligns with a particular objective (such as a learning goal).

The scores obtained from the experts are used to calculate the IOC according to the following formula:

$$IOC = \frac{\sum R}{N}$$

where: *IOC* is an index showing how consistent the content is with the objectives

ΣR is the sum of the experts' scores

N is the number of experts

The sum of the scores for each question is found by adding all expert scores for each item and then dividing by the number of experts. Then the results are compared with the set criteria for the other items. This is done for every question.

Table 1. Expert Evaluation of Content-Objective Congruence

Assessment checklist	IOC value	Evaluation results
Unit 1: Solar Energy		
- Aligned with objectives	1.00	Applicable
- Appropriate content coverage for training duration	1.00	Applicable
- The content is relevant and aligned with the learning objectives of the instructional package.	0.80	Applicable
- Content validity	0.80	Applicable
Unit 2: Wind Energy		
- Aligned with objectives	0.80	Applicable
- Appropriate content coverage for training duration	1.00	Applicable
- The content is relevant and aligned with the learning objectives of the instructional package.	0.80	Applicable
- Content validity	0.80	Applicable
Unit 3: Water Energy		
- Aligned with objectives	0.80	Applicable
- Appropriate content coverage for training duration	0.80	Applicable
- The content is relevant and aligned with the learning objectives of the instructional package.	0.80	Applicable
- Content validity	1.00	Applicable
Unit 4: Biomass Energy and Biogas		
- Aligned with objectives	0.80	Applicable
- Appropriate content coverage for training duration	1.00	Applicable
- The content is relevant and aligned with the learning objectives of the instructional package.	0.80	Applicable
- Content validity	1.00	Applicable

Experts score each item as follows (K. Anongnat & M. Nataporn, 2022):

- Assign a score of +1 if they are certain that the question measures the intended learning objective.
- Assign a score of 0 if they are unsure whether the question measures the intended learning objective.
- Assign a score of -1 if they are certain that the question does not measure the intended learning objective.

The IOC is a measure of inter-rater reliability, indicating the degree of agreement among the experts in their ratings.

IOC values typically range from 0 to 1, with higher values indicating greater agreement (K. Anongnat & M. Nataporn, 2022).

• IOC values between 0.50 and 1.00 represent acceptable inter-rater reliability, suggesting that the experts' ratings are reasonably consistent.

• IOC values below 0.50 indicate poor inter-rater reliability, implying that the experts' ratings are not sufficiently consistent and require further evaluation and potential revision.

IOC values from 0.50-1.00 indicate questions that are usable while values lower than 0.50 suggest that questions are not usable and must be improved.

5.4.2 Instructional Media Evaluation

The instructional media of the teaching package for the curriculum training in science, technology, engineering, and mathematics using renewable energy project-based investigation for high school students was assessed by experts. Their evaluations of the appropriateness of each teaching kit followed the interpretation criteria evaluating scores according to the model of Best and Kahn (1998) as follows.

An average score of:

4.50-5.00 indicates that the content is appropriate and satisfies criteria at the highest level.

3.50-4.49 means that there is a high level of appropriateness/satisfaction.

2.50-3.49 means that the item is appropriate and satisfies criteria at a moderate level.

1.50-2.49 indicates that there is a low level of suitability and satisfaction.

0.00-1.49 indicates the lowest level of appropriateness/satisfaction.

The results showed a content aspect of X = 4.60. The instructional media is divided into content preparation (X = 4.40), content presentation with demonstration kits (X = 4.50), and measurement and evaluation (X = 4.50), as shown in Table 2. These values indicate the highest level of appropriateness.

Table 2. Evaluation Results of Training Curriculum Teaching Materials by Experts and Qualified Reviewers

Assessment checklist	Evaluation results	Deviation	Purpose of evaluation
1. Content			
Mean	4.60	0.55	Most appropriate
2. Instructional media			
PowerPoint content preparation			
Mean	4.54	0.58	Most appropriate
Instructional content delivery			
Mean	4.45	0.52	Highly appropriate
3. Measurement and evaluation outcomes			
Mean	4.55	0.52	Most appropriate

5.4.3 Evaluation of Difficulty Level and Discrimination Power of the Exam Questions

The teaching package for the curriculum training in science, technology, engineering, and mathematics using renewable energy project-based investigation was tested with 85 students in grades 10 and 11 in the science-math-pre-engineering program at Satrinonthaburi School (a high school in Nonthaburi Province, Thailand). The results of exam question evaluation in terms of difficulty level showed that the questions had appropriate difficulty, and evaluation showed good discrimination power.

5.5 STEM Learning Process

The steps for implementing all the developed teaching materials and conducting teaching and learning activities with students follow the STEM integrated learning process model which consists of 5 steps: Ask, Imagine, Plan, Create, and Improve, as shown in Figure 2. The researchers analyzed the data, including analysis of the quality of the tests, determination of the learning outcomes of the students, analysis of the effectiveness of the created teaching package, and interpretation of the evaluation forms. Instructional material evaluation and assessment is a systematic process that measures and evaluates the quality of instructional materials to ensure their effectiveness in promoting student learning and achieving educational objectives.

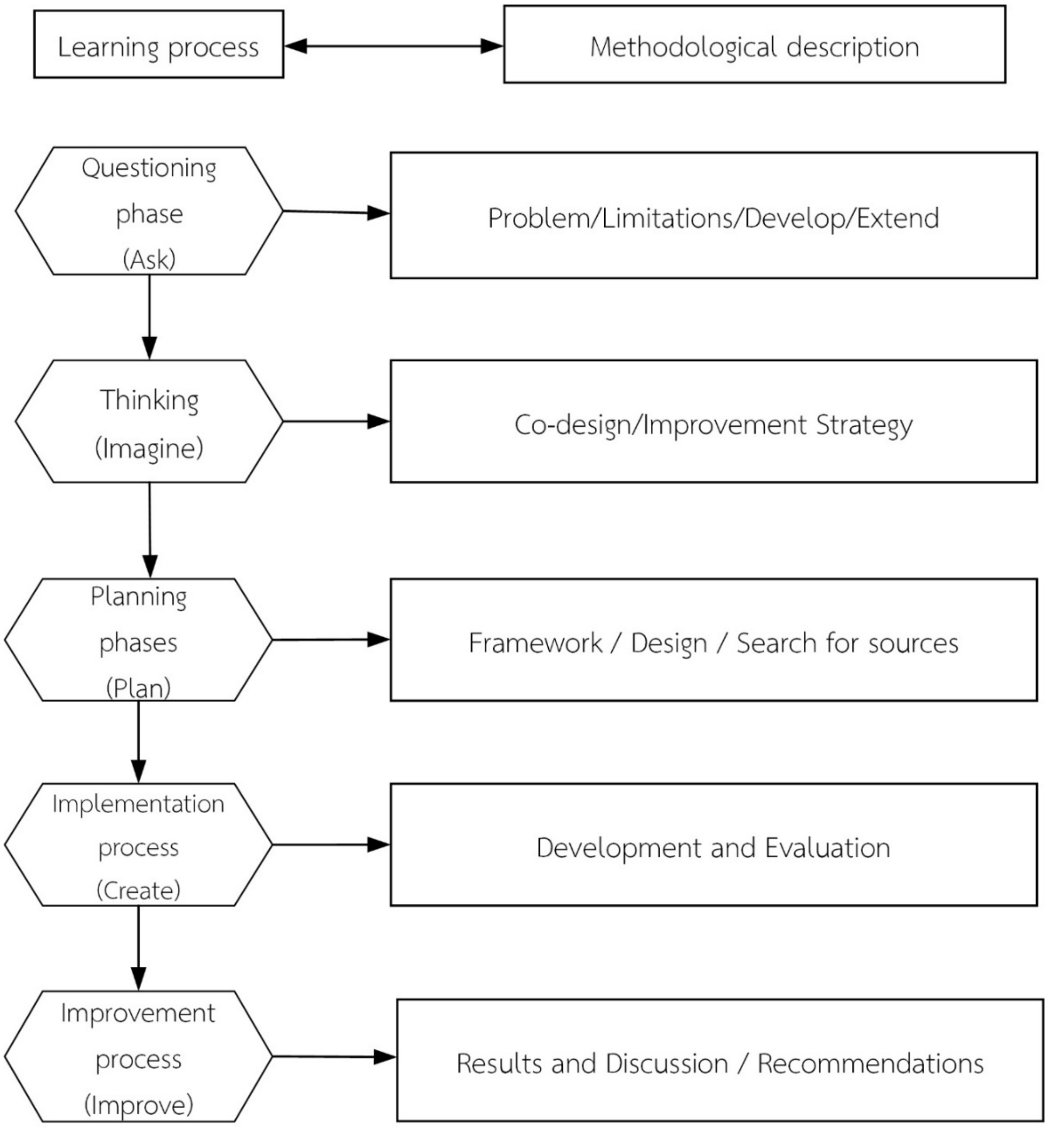

Figure 2. STEM Model of the Integrated Research Learning Process

6. Results

The current study aims to develop and evaluate a training package in science, technology, engineering, and mathematics using renewable energy project-based investigation for high school students. The researchers developed a curriculum and research tools, including a renewable energy project teaching package based on an integrated STEM learning model. The research results consist of the following parts.

6.1 Four Energy Teaching Packages

Four energy teaching packages of the curriculum training in high school education that integrate renewable energy-based projects were investigated, as depicted in Figures 3-5. The packages include solar energy, wind energy, and hydropower modules, as well as a unit on biomass and biogas energy. Each renewable energy project has a working process starting from the input of energy and converting the energy form, such as solar into electrical energy. This may involve connection to a control unit or battery charger, and use a battery for applications or connections to electrical loads (Figure 3). For wind energy, the researchers had the learners design horizontal and vertical wind turbines. When a wind turbine rotates, it generates mechanical energy. A small generator was designed using permanent magnets with current passing through copper wire to produce electrical energy, which is then used to charge batteries for further applications. For hydro-energy (Figure 4), turbine rotation by water mass is used. When a water turbine rotates, mechanical energy can be converted to electrical energy. This technique is also employed with wind power. Finally, a biomass fuel stove was designed (Figure 5), with the biomass consisting of branches or paper. The learners also studied the generation of biogas from waste fermentation.

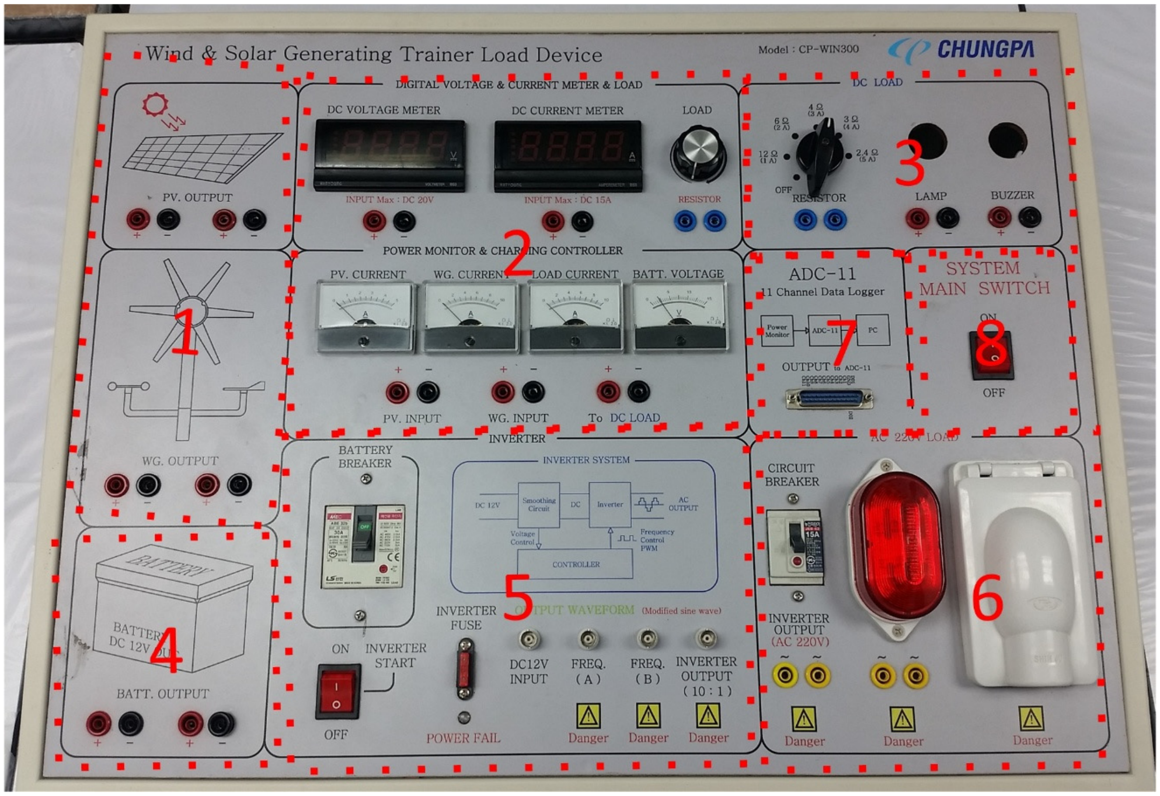

Figure 3. Solar and Wind Energy Experimental Setup, 1) connection point for solar panels and wind turbines, 2) set to display measurement results at various points such as voltage and current values, 3) adjustable resistance load connection, light bulb, and audible alarm, 4) battery connection point, 5) inverter circuit set to convert to AC power, 6) AC load connection set, 7) port connected to computer, and 8) on-off power switch.

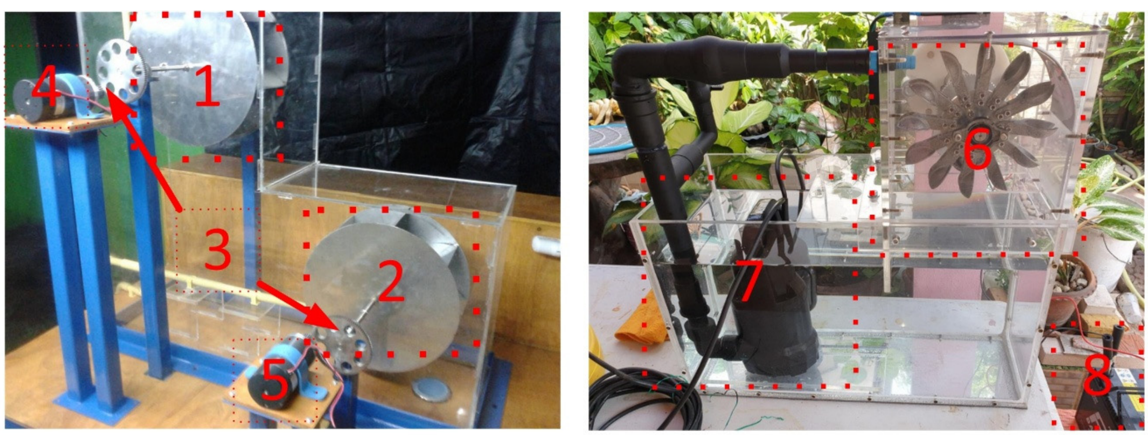

Figure 4. Experimental Water Turbine, 1) vertical water turbine, 2) horizontal water turbine, 3) reduction gears, 4) vertical water turbine generator, 5) horizontal water turbine generator, 6) Pelton type water turbine, 7) water pump, and 8) battery.

The operation of this equipment allows experiments with solar energy, wind energy, and a hybrid mode using both energy forms together. One can learn to convert solar energy into electrical energy for battery storage. This approach can also convert wind energy into electrical energy with final storage in a battery. An inverter is employed to convert DC to commonly used AC power.

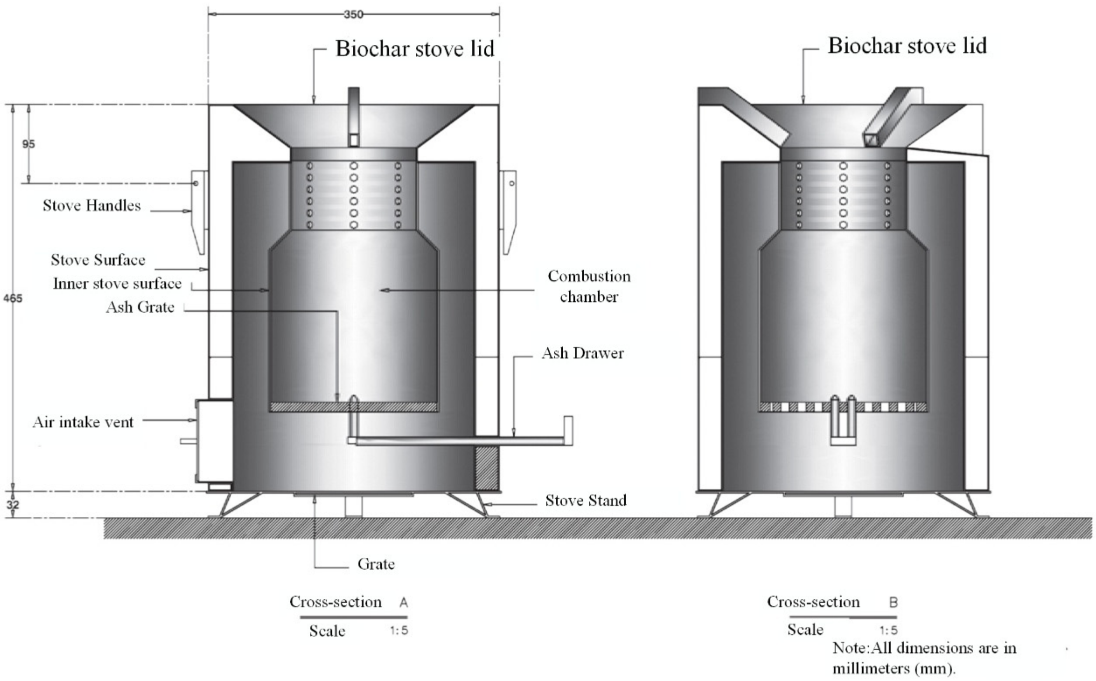

Figure 5. Biomass Stove Design [17]

6.2 Learning Achievement

Learning achievement before and after studying the curriculum training package in science, technology, engineering, and mathematics using renewable energy project-based investigation was evaluated. The post-study test scores of each of the four learning units were obtained. The modules included Learning Unit 1-Solar Energy, Learning Unit 2-Wind Energy, Learning Unit 3-Hydro-energy, and Learning Unit 4-Biomass and Biogas Energy.

Conducting In-class Assessments: The E1/E2 training course evaluation criteria is a method for evaluating the effectiveness of training courses. Considering both the learning process and learning outcomes of the trainees, the first 80 points (E1) represent the percentage of the average score of the entire sample on a performance evaluation according to the worksheets and the post-test in each learning unit. E2 indicates the percentage of the average score of the entire sample on an academic achievement test focused on evaluating the learning outcomes of trainees. It ascertains that the objectives of the curriculum have been achieved as specified by the curriculum according to the 80/80 criteria so the E1 and E2 scores are both greater than or equal to 80%.

The E1/E2 criteria are not fixed standards. They can be adjusted as appropriate for each department or educational institution depending on various factors such as the context in which the learning is organized.

Four in-class quizzes were administered throughout the course, each worth 10 points, for a total of 40 points. The overall average score (E1) for all students was 32.04 points, representing an 80.10% achievement. Post-course Assessment: A comprehensive post-course assessment was conducted, covering all four lessons. The total (E2) score for this assessment was 40 points. The overall average score for all students was 32.2 points, representing an 83.00% achievement, which is higher than the 80/80 criteria for success, as shown in Table 3. Therefore, the case study teaching package developed by the researchers has value since its performance exceeds the set criteria.

Table 3. Training Program Analysis

Score	Number of students	Maximum score	Average score	Standard deviation	Mean score (%)
Unit Post-test (E1)	25	40	32.04	1.24	80.10
Post-instruction assessment (E2)	25	40	32.20	3.39	83.00

6.3 The Pre / Post Study Achievement for Teaching Student

Learning achievement before and after the training curriculum: The pre-study and post-study achievement tests from using the teaching package on science, technology, engineering, and mathematics employing renewable energy project-based investigation compared the pre-test and post-test scores. This was done to determine whether there was a statistically significant difference using a dependent t-test method. The analysis results are shown in Table 4.

Table 4. Analysis of Pre- and Post-Test Scores for Integrated Learning Methods

List	Number of students	Maximum score (%)	Average score (%)	Mean score (%)	Standard deviation	t	P
Pre-test	25	40	19.92	49.80	2.54	18.82	<.001
Post-test	25	40	32.04	80.10	1.24		

Statistical significance is at the α=0.05 level.

From Table 4, the pre-study test scores averaged 19.92 (49.80%) with a standard deviation of 2.54. The post-study test scores averaged 32.04 (80.10%) with a standard deviation of 1.24. The t-statistic was 18.82 with a statistical significance of $p < .001$, which is less than α=0.05, indicating that the learners' achievement before and after studying was significantly different (Prasong & Chaiyapon, 2019).

6.4 Results of a Satisfaction Assessment

Results of a satisfaction assessment of students who received the training under the developed curriculum and a comparison of their learning achievement are presented in Table 5.

Table 5. Evaluation of Student Satisfaction with Instruction

Assessment checklist	Mean	S.D.	Evaluation Results
1. Instructional Effectiveness Average	3.61	0.78	high
2. Average Content on Renewable Energy	3.71	0.74	high
3. Mean of Instructional Documents and Resources	3.57	0.77	high
4. Assessment and Evaluation Mean	3.62	0.65	high
Overall Mean	**3.63**	**0.74**	high

In an analysis of student satisfaction after teaching and learning, the researchers used a questionnaire for student opinions examining 4 areas. These are 1) teaching and learning management, 2) renewable energy content, 3) documents and learning media, and 4) measurement and evaluation. A 5-level evaluation form was used with an interpretation of the evaluation criteria of scores according to (Best & Kahn, 1998):

An average score of:

4.50-5.00 indicates the highest level of suitability/satisfaction.

3.50-4.49 shows there is a high level of suitability/satisfaction.

2.50-3.49 indicates a moderate level of suitability/satisfaction.

1.50-2.49 means there is a low level of suitability/satisfaction.

1.00-1.49 indicates the lowest level of suitability/satisfaction.

The study results are summarized as follows. Analysis of student group satisfaction: After completing the STEM integrated teaching and learning, the researchers used a questionnaire to assess the opinions of students who studied using the integrated method. A 5-level opinion assessment form was used, divided into four aspects: teaching and learning management, renewable energy content, documents and instructional media, and measurement and evaluation (Dumulescu, et al., 2021). From Table 5, learners who studied using the integrated learning method had the highest satisfaction in teaching and learning management (average 3.61), content (average 3.71), measurement and evaluation (average 3.62), followed by teaching and learning management (average 3.61), and documents and instructional media (average 3.57). Overall, the learners who studied using the integrated learning method had an overall average score of 3.63 across all aspects, which is in the high score range and agrees with the research hypothesis.

7. Conclusions

The results of the content quality evaluation: An analysis of the appropriateness of the integrated learning method was conducted based on the opinions of ten experts. It was found that the teaching package was consistent across all four learning units. The consistency evaluation was in the range of 0.80-1.00, which indicates that the evaluation can be used.

7.1 Effectiveness of the Curriculum Training Development

The sample group scored 80.10% on the post-lesson tests of each learning unit (E1) and 83.00% on the post-study achievement test (E2). The students' learning achievement is 80.10/83.00, which exceeds the hypothesized 80/80 scores. Therefore, the case study teaching package developed by the researchers has an effectiveness higher than the set criteria.

7.2 Learning Achievement before and after the Curriculum Training Development

The pre-study test scores averaged 19.92, an average score of 49.80% with a standard deviation of 2.54. The post-study test scores averaged 32.04, an average score of 80.10%, and a standard deviation of 1.24. The t-statistic was 18.82 with a significance of $\alpha<.001$, which is less than 0.05, showing that the learners' achievement after studying was significantly higher than before, indicating that the null hypothesis can be rejected in favor of the specified research hypothesis.

7.3 Results of the Instructional Media Quality Evaluation by Experts

It was found that the content aspect had an average of 4.60, indicating the highest level of appropriateness. Instructional media is divided into PowerPoint content preparation (average 4.54, the highest level of appropriateness), content presentation with teaching packages (average 4.45, a high level of appropriateness), and measurement and evaluation (average 4.55, the highest level of appropriateness).

7.4 Results of the Analysis of the Difficulty Level and Discrimination Power of the Exam Questions

The teaching package on curriculum training development and case studies was evaluated from the participation of 85 students at the secondary level at Satrinonthaburi School with a total of 40 exam questions. Evaluation of the exam questions in terms of difficulty level showed that the questions had appropriate difficulty, and evaluation showed good discrimination power. (Difficulty level: rather difficult-15 items, appropriate-17 items, rather easy-8 items) (Discrimination power: very good-13 items, good-21 items, and fair-6 items).

7.5 Results of the Student Group's Satisfaction with the Curriculum Training Development

Student satisfaction was at a very good level. The appropriateness of the manual/content had an average of 3.71, the appropriateness of the instructional media structure averaged 3.57, and the appropriateness of usability had an average of 3.63.

Therefore, it can be concluded that the curriculum teaching package, when used with the integrated teaching and learning process model, has an effectiveness that meets the specified standard criteria. It can be appropriately used in teaching and learning about renewable energy and encourages learner interest in further developing renewable energy in the country and pursuing higher education.

8. Discussion

Learning management was developed based on the curriculum training guidelines in science, technology, engineering, and mathematics using renewable energy project-based investigation for secondary school students. The results showed that the students had higher post-learning scores than pre-learning scores. This can be measured by the student's ability to design and create renewable energy projects. The activities in each step help students develop thinking skills. Students have practiced learning from the learning units. The instructor provided opportunities for students to think and further develop the renewable energy around them, practice teamwork, and focus on the students' interests as the main concern, without limiting the students' ideas, allowing them to express their thoughts in various ways. This is consistent with (Pichaya & Wisud, 2021), who state that an atmosphere that fosters creativity is one filled with acceptance and encourages free expression of opinions. Allowing children to explore and study on their own supports their creativity. Moreover, this activity is a learning process that helps promote student participation in activities that foster creativity and can lead to innovation. The design and development of the teaching package, which used a cross-subject integrated learning model, revealed its high appropriateness (Winit et al., 2020). The teaching package was also applied to the integrated teaching and learning model that focuses on spurring learner interest, understanding content, applying the content for further development, as well as analyzing and summarizing the test results obtained through group activities. From this teaching and learning management process, learners develop knowledge, practical skills, and a positive attitude toward studying renewable energy. This is consistent with the research of (Chatmongkol et al., 2021), who studied the results of learning management based on STEM education guidelines to promote STEM habits of mind. Regarding the curriculum training development, it was found that the effectiveness of the curriculum training was higher than the set criteria of 80/80. The students' learning achievement was 80.10/83.00, which exceeds the hypothesized 80/80 value. Therefore, the case study teaching package developed by the researchers has an effectiveness higher than the set criteria. This is consistent with (Atthaphong, 2024) findings that the development of a STEM education curriculum using computer application project-based learning for secondary school students resulted in post-learning test scores that were significantly higher than pre-learning scores at an α=.05 level, with values of 81.10/80.70. The results indicated that the program was effective in enhancing the participants' leadership competencies. The mean pre-test score was 80.12, and the mean post-test score was 80.64, which exceeded the established criterion of 80/80. Additionally, the participants' satisfaction with the program was high. Subsequently, an integrated teaching and learning process was designed that focuses on students understanding the problem and developing existing knowledge by analyzing the conditions or limitations of the surroundings to define the scope of the problem. This is done by applying relevant information and concepts, leading to the design and creation of work products, providing new knowledge content, hands-on practice, knowledge sharing within the group and classroom, and measurement and evaluation. The result is that learners have increased learning progress. This is consistent with the work of (Hermann & Bossle, 2020), who synthesized a model for applying embedded systems technology to develop computer projects based on STEM education guidelines. Such an approach helps learners develop five competencies according to the core curriculum. Additionally, learners have a desire to learn and creatively become innovators. It is also consistent with (Prasong & Chaiyapon, 2019) with a mean of 4.15 in achievement using the integrated unit. Before learning, students had a mean pre-test score of 11.09 (36.97%). After learning, their post-text mean score was 23.00 (76.67%). Learning was an average of 11.91 points (39.70%) higher than before learning, exceeding the 70% criteria at an α=.01 level of significance. It was found that the results of the learners' satisfaction assessment in terms of appropriateness of the manual/content was an average of 4.30, the appropriateness of the program structure had an average of 4.25, and the appropriateness of usability averaged 4.32. The learners' satisfaction was at a very good level. The developed teaching and learning model focuses on learner participation, using an integrated model with a clear and appropriate sequence of steps (Anongnat & Nataporn, 2022). This motivates learners and they become more attentive. Additionally, learners are satisfied and interested in using renewable energy teaching materials, as well as being satisfied with the teaching and learning process (Landry, et al., 2013). This process creates interaction between the instructor and learners through brainstorming, group activities, knowledge exchange, data presentation, and appropriate evaluation forms. The approach helps motivate learners to learn and solve problems appropriately. Learners then apply knowledge from multiple disciplines to develop project work products. It is also consistent with (Parks, et al., 2018), who studied training course participant satisfaction evaluation results on classroom action research. It was found that the trainees were satisfied at the highest level ($\bar{x}$=4.61, S.D.=0.49).

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Authors contributions

Sathaporn Sitthiwong: Investigation, methodology, data curation, software, writing—original draft. Chaiyaphon Thongchaisuratkool: Supervision, visualization, validation, resources, writing- review and editing. All authors have read and agreed to the published version of the manuscript.

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