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The Development of a Protecting the World Science Club Activities Curriculum Based on Challenge-Based Learning Collaborative Systems Thinking to Enhance Complex Problem-Solving Competency Among Hight School Students

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Abstract

This research aimed to (*1)* investigate global threatening issues impacting Thailand, with the aim of promoting complex problem-solving competency among High School Students. (2) develop and validate the quality of a protecting the world science club activities curriculum designed to foster complex problem-solving competency in high school students. (3) implement and evaluate a protecting the world science club activities curriculum for enhancing complex problem-solving competency among high school students. And, (4) assess high school students' satisfaction with the protecting the world science club activities curriculum in relation to its effectiveness in promoting complex problem-solving competency. This research and development study employed a sample of *20* high school students from Padoongrasdra school during the second semester of the *2024* academic year. Research instruments included the "Protecting the World Science Club Activities Curriculum," its user manual, a complex problem-solving competency assessment, and a student satisfaction questionnaire. Data analysis involved descriptive statistics, specifically mean and standard deviation. The results of the study found that:1. A study investigated global threats impacting Thailand to foster complex problem-solving competency among high school students. Key issues identified include: 1) urban waste crisis, 2) global boiling crisis, 3) widespread flooding, 4) PM *2.5* air pollution, and 5) cybercrime. *2.* The development of the protecting the world science club activities curriculum resulted in a comprehensive framework comprising six key components: 1) Rationale and Significance of the Curriculum, 2) Principles, 3) Learning Outcomes, 4) Structure of Student Development Activities, 5) Guidelines for Learning Management, and 6) Guidelines for Measurement and Evaluation. Overall, the Protecting the World Science Club Activities demonstrated a high level of appropriateness. 3. Students demonstrated the highest level of complex problem-solving competency after completing the comprehensive curriculum. And, 4. Students expressed a high level of satisfaction with their participation in the protecting the world science club activities curriculum overall.

Keywords: Curriculum, Club Activities, Challenge-Based Learning, Systems Thinking, Complex Problem-Solving Competency

1. Introduction

Complex problem-solving competency is recognized as a foundational skill for all 21st-century professions (Fischer & Neubert, 2015). The Organization for Economic Co-operation and Development (OECD) has consistently assessed students' problem-solving competency alongside other literacies in the Program for International Student Assessment (PISA) to evaluate countries' preparedness in equipping their youth. The initial assessment of problem-solving competency by the OECD began in 2013 and evolved into Collaborative Problem Solving in the 2015 assessment (OECD, 2013). Results from Thai students in 2015 revealed that approximately 42.9% were at Level 1 out of 6 for problem-solving ability, indicating proficiency only with less difficult or uncomplicated problems and a deficiency in complex problem-solving competency through collaborative group work (PISA Thailand, 2018). This finding suggests Thai students struggle to connect classroom learning with real-world problem-solving, aligning with Sangthong (2010) and Kamtha (2014), who observed that Grade 7 students lacked the ability to apply scientific knowledge from class to explain or resolve daily issues. Complex problem-solving competency involves overcoming obstacles between a current situation and a desired goal, requiring the integration of knowledge, intellect, emotional intelligence, and psychological factors (Funke as cited in OECD, 2013). Therefore, problem-solving is considered a core competency (OECD, 2013). Complex problem-solving shares this definition but involves situations with multiple interconnected variables (connectivity), dynamic elements (time-sensitive and dependent on prior outcomes), intransparency (unclear variables and relationships), and potentially conflicting multiple goals (Funke, 2012). Contemporary global challenges such as urban waste, global boiling crisis, PM 2.5 dust, floods, and cybercrime are all complex problems that necessitate educational systems prepare youth with advanced problem-solving skills. The PISA 2012 framework (OECD, 2013) outlines a four-step problem-solving process: 1) Exploring and understanding the problem, where students observe and analyze the situation, identify relationships, constraints, and obstacles, and then comprehend the information to find solutions; 2) Representing the problem, where students describe the problem by analyzing and connecting data and presenting relevant information comprehensibly; 3) Planning and executing a solution, involving systematic planning and implementation to manage and resolve the problem, leading to a conclusion; and 4) Monitoring and reflecting on the plan's implementation, where students track and verify results during and after execution, evaluating the suitability of the solution. This research adopts the Collaborative Problem-Solving framework from PISA 2015, which is an advancement of the PISA 2012 problem-solving competency, emphasizing collaborative work skills in the problem-solving process. This dual focus adds a challenging dimension for both the researcher as an instructor and students unfamiliar with this learning approach. The Institute for the Promotion of Teaching Science and Technology (2013) highlights the development of scientific communication skills in science and technology education, focusing on expressing, exchanging, presenting, and accurately conveying scientific knowledge to foster shared understanding. This aligns with the Office of Knowledge Management and Development (2019), which identifies complex problem-solving competency as a crucial skill for life and work in the 21st century.

A significant challenge observed among high school students stems from their consistently low average scores on the PISA assessment at the ninth-grade level. This indicates a deficiency in complex problem-solving competency, wherein students struggle to apply acquired knowledge, generate new ideas, and adapt existing concepts to create novel solutions. Specifically, in 2023, 60% of students demonstrated a lack of understanding of fundamental principles in physics, particularly concerning various types of motion, and were unable to apply or articulate their knowledge effectively. A review by the Ministry of Education (2017) revealed an inadequacy of clear and sufficient indicators for developing complex problem-solving skills, likely due to the relatively nascent recognition of this competency. Consequently, there is a clear need to develop curricula that foster complex problem-solving competency in students, aligning with their interests. An analysis of the existing curriculum at Phadungrat School suggests that a club activity curriculum would be an effective approach. A survey of high school science students indicated a strong interest in a "Protecting the World Science Club" curriculum, utilizing a challenge-based learning and collaborative systems thinking framework to enhance complex problem-solving competency for high school students in the current era of global threats. This aligns with the Ministry of Education's guidelines for club activities. Research on developing complex problem-solving skills points to challenge-based learning as a popular and effective pedagogical approach in contemporary education. Notably, Apple Inc.'s "Challenge Based Learning: Take action and make a difference" initiative, which evolved from their innovation and product development processes, has been successfully implemented in schools across the United States to empower students within communities to effectively tackle complex problems and appropriately extend their learning beyond traditional subjects through self-directed inquiry. Challenge-based learning is an instructional strategy that immerses learners in authentic, real-world challenges, with the goal of developing their complex problem-solving skills, critical thinking, collaboration, and capacity for continuous innovation. This is achieved through a process of self-discovery and the creation of innovative solutions by the students themselves. In a rapidly evolving world facing increasingly complex challenges, education must adapt to equip students with the readiness to confront these real-world demands.

Challenge-Based Learning (CBL) is an educational approach that fosters skills essential for the 21st century, such as critical thinking, problem-solving, collaboration, and innovation, by engaging students in tackling real-world, complex problems. As outlined by Nichols and Cator (2008), CBL typically commences with a Big Idea where students formulate questions about a problem's causes, factors, and impacts. This leads to an Essential Question, allowing for a clearer understanding of the issue.

Educators then present a challenging problem or situation for students to explore and analyze, understanding its scope and complexity. This is followed by planning and designing solutions, which may involve experimentation or prototyping, and then taking action to implement their plans. Students subsequently present their work, explaining their problem-solving process, and engage in reflection and assessment with teachers to evaluate the learning process and outcomes. This challenge-based pedagogy also promotes systems thinking, a holistic approach to understanding problems by considering the interactions of all internal and external components, with roots in various disciplines including science, engineering, and social sciences, notably advanced by Ludwig von Bertalanffy's General Systems Theory. Systems thinking is crucial for complex problem-solving as it enables students to grasp the overall picture, identify root causes, devise comprehensive solutions, and anticipate potential consequences, fostering smarter and more effective decision-making. Students can apply systems thinking by analyzing problems, creating diagrams like relationship or causal loop diagrams, simulating scenarios, identifying solutions that positively impact the entire system, and evaluating results for sustainability. The Challenge stage involves students setting sub-goals and engaging in observation-based inquiry, guided by workshops led by experts who impart theoretical knowledge and facilitate practical application and collaborative interaction. Finally, in the Solution phase, students meticulously implement each step, disseminating their work and critically analyzing strengths and weaknesses for refinement. The process culminates in Assessment, where students present their solutions and innovations, evaluated for content accuracy, communication clarity, and the practical benefits derived from their participation. Recognizing the importance of these approaches, particularly in light of John D. Sterman's (2002) work on Systems Thinking and Modeling from MIT Sloan School of Management, this research aims to develop a "Science for Global Protection" club curriculum grounded in Challenge-Based Learning Collaborative Systems Thinking to enhance complex problem-solving competency among high school students, equipping them to effectively address disaster-related challenges.

The development of a "Protecting the World Science Club Activities Curriculum" based on challenge-based learning and collaborative systems thinking aims to cultivate complex problem-solving competency among High School Students. This curriculum is designed to encourage students to apply their knowledge from science and technology subjects to address threats originating from natural phenomena or human activities. The initiative stems from a global awareness of intensifying environmental issues, including urban waste overload, global boiling crisis, flooding, PM2.5 pollution, and cybercrime. It emphasizes the critical importance of fostering environmental consciousness in youth, empowering them with complex problem-solving competency by leveraging scientific and technological knowledge to collectively identify and devise solutions through "Protecting the World Science Club" activities, scientific experiments, and community-based environmental project design. Recognizing the significance of instilling environmental awareness in young people, many schools globally acknowledge the necessity of integrating this curriculum to support an activity-based program that prioritizes integrated learning and the development of 21^{st}-century skills, thereby creating opportunities for youth to collaborate on resolving contemporary issues.

This study aims to develop a "Protecting the World Science Club Activities Curriculum" grounded in challenge-based learning and collaborative systems thinking. The curriculum is designed to enhance complex problem-solving competency in High School Students by encouraging them to apply their knowledge from science and technology subjects to address threats originating from natural phenomena and human activities. The initiative for this curriculum stems from a global recognition of escalating environmental issues, such as urban waste saturation, global boiling crisis, widespread flooding, PM2.5 pollution, and cyber fraud. Instilling environmental awareness and cultivating complex problem-solving skills in youth is paramount, achieved by enabling them to collaboratively identify and devise solutions through various activities within the science club, including scientific experiments and community-based environmental project design. Schools worldwide acknowledge the critical role of fostering environmental consciousness in younger generations. Therefore, integrating the "Protecting the World Science Club Activities Curriculum" into the educational framework is essential to support the development of an activity-based curriculum that emphasizes integrated learning and the cultivation of 21^{st}-century skills, thereby providing opportunities for youth to collaborate on addressing contemporary challenges.

Therefore, conducting research to develop activity-based teaching curricula grounded in Challenge-Based Learning (CBL) and collaborative systems thinking is of paramount importance. This approach aims to enhance complex problem-solving competency among high school students to a higher level, enabling them to effectively address daily threats in their communities, including navigating complex situations and developing alternative solutions. Such a curriculum will foster their ability to collaborate with others and cultivate leadership qualities essential for achieving shared goals. Furthermore, this initiative promotes lifelong learning by nurturing innovative thinking skills and supporting continuous development in an ever-changing environment. By equipping students with complex problem-solving competency, this educational framework acts as a vital mechanism for national and social development, paving the way for future economic and social advancement in Thailand. This is achieved through CBL and collaborative systems thinking processes that encourage problem-solving, experimentation, and the cultivation of a supportive, collaborative environment where knowledge and understanding are intrinsically linked to students' real-life experiences.

2. Objective

The present study aimed to examine the following objectives:

1. To investigate global threatening issues impacting Thailand, with the aim of promoting complex problem-solving competency among High School Students.

2. To develop and validate the quality of a protecting the world science club activities curriculum designed to foster complex problem-solving competency in high school students.

3. To implement and evaluate a protecting the world science club activities curriculum for enhancing complex problem-solving competency among high school students.

4. To assess high school students' satisfaction with the protecting the world science club activities curriculum in relation to its effectiveness in promoting complex problem-solving competency.

3. Research Methodology

3.1. Research Methodology

This research employs a Research and Development (R&D) design. Data will be collected using appropriate research instruments and subsequently analyzed through suitable processes. The findings will then be presented using Descriptive Analysis. This research has been designed to comprehensively address ethical considerations with due diligence. Furthermore, the efficacy of the research instruments was rigorously evaluated by qualified experts to ensure the utmost appropriateness and validity of the study.

3.2. Research Area, Population, and Sample

The research was conducted in Padoongrasdra School, Phitsanulok, Thailand. Moreover, The study population comprises four distinct groups:

1) Key Informants for Curriculum Development: This group includes experts in science communication, curriculum and instruction, and challenge-based learning and systems thinking.

2) Curriculum Evaluators: This group consists of university lecturers and schoolteachers.

3) Complex Problem-Solving Competency Evaluators: This group comprises high school students.

4) Satisfaction Evaluators: This group also comprises high school students. The researchers selected samples for convenience in data collection, with specific details outlined below:

1) Key Informants for Curriculum Development: Three individuals selected using Snowball Sampling.

2) Curriculum Evaluators: Three individuals selected using Purposive Sampling based on the following criteria:

2.1) Minimum educational qualification of a Master's degree.

2.2) Expertise in curriculum and instruction, measurement and evaluation, or challenge-based learning and collaborative systems thinking.

2.3) A minimum of five years of professional experience in an educational institution or university.

3) Complex Problem-Solving Competency Evaluators: Twenty high school students selected using Purposive Sampling from students enrolled in the "Protecting the World Science Club Activities" during the second semester of the 2024 academic year.

4) Satisfaction Evaluators: Twenty high school students selected using Purposive Sampling from students enrolled in the "Protecting the World Science Club Activities" during the second semester of the 2024 academic year.

3.3. Research Instruments

The study will utilize the following instruments:

1) Semi-structured interview protocol on global threatening issues impacting Thailand for promoting complex problem-solving competency in high school students.

2) Evaluation form for the suitability of the protecting the world science club activities curriculum.

3) Assessment rubric for complex problem-solving competency in high school students.

4) Satisfaction questionnaire.

3.4. Data Collection

1) Investigation of global threatening issues impacting humanity and Thailand, essential for developing the protecting the world science club activities curriculum, utilizing challenge-based learning and collaborative systems thinking to enhance complex problem-solving competency in high school students.

2) Development and quality assurance of the protecting the world science club activities curriculum, designed to foster complex problem-solving competency in high school students through challenge-based learning and collaborative systems thinking. The curriculum will be designed, evaluated for suitability by experts, and subsequently revised based on their recommendations.

3) Implementation of the protecting the world science club activities curriculum. The curriculum will be piloted with students enrolled in the protecting the world science club activities, followed by an assessment of their complex problem-solving competency.

4) Evaluation of student satisfaction with the protecting the world science club activities curriculum. After students complete the curriculum, the researchers will administer a satisfaction questionnaire to summarize the data and present the research findings.

3.5. Data Analysis

1) Qualitative Data: The researchers will analyze qualitative data according to the study's objectives using interpretation, derived from interviews, to summarize key themes across data groups and analyze the relationships between the data.

2) Quantitative Data: The research team will analyze quantitative data obtained from the evaluation forms using appropriate statistical software. This will involve Descriptive Statistics, presenting the results as means and standard deviations.

4. Results

In this research study, the collected data were categorized and the findings presented in accordance with the pre-defined research objectives. The results of this study can be summarized as follows.

The research results found that the investigators established learning units requiring student engagement, with experts identifying and proposing five critical global and Thai-specific threats: 1) urban waste overflow, 2) flooding, 3) global boiling crisis, 4) PM 2.5 pollution, and 5) cybercrime. These insights informed the design of learning activities for the "Science for World Protection Club" curriculum, ensuring alignment with students' age, developmental stage, and interests. The pedagogical approach adopted challenge-based learning, characterized by open-ended problems with multiple potential solutions, fostering systems thinking to encourage multi-dimensional analysis, particularly for real-world scenarios. The emphasis on diverse learning, including classroom discussions and idea exchange, promoted learning from varied perspectives, thereby enhancing complex problem-solving competency. Crucially, the use of open-ended tasks with multiple response options encouraged students to analyze problems from various angles, fostering a more sophisticated worldview. Presenting authentic external problems, such as community-based issues, ensured activities were meaningful and relevant to students' lives, highlighting the practical application of learning. Experts recommended framing multi-faceted problems that encourage analytical thinking and multi-dimensional problem-solving, especially those rooted in real-world societal contexts. Furthermore, integrating real-world problems, such as environmental or social challenges, was suggested to underscore the significance of complex problem-solving and its real-life applicability. The inclusion of simulated or virtual scenarios would provide hands-on experience in problem-solving within realistic contexts. Embedding ethical considerations throughout all learning activities was deemed essential to cultivate responsible behavior and the appropriate application of knowledge. The curriculum should also prioritize the development of essential characteristics for confronting threats and complex issues, including resilience, creativity, and collaboration. Ultimately, the pedagogy advocated for significant student-led, hands-on challenges, with continuous teacher monitoring of student innovation and the integration of new knowledge for practical application.

The research results found that the researchers designed a club activity curriculum based on the principles of Challenge-Based Learning and Collaborative Systems Thinking. This curriculum, termed the "Protecting the World Science Club Activities Curriculum," comprises the following key components: 1) rationale and significance of the problem, 2) guiding principles, 3) learning outcomes, 4) structure of student development activities, 5) guidelines for implementing Challenge-Based Learning and Collaborative Systems Thinking, and 6) approaches to measurement and evaluation. The curriculum also outlines specific learning units and content.

Table 1. Curriculum Outlines the Learning Units and Content Areas for Protecting the World Science Club Activities Curriculum (20 Instructional Hours)

Learning Units	Learning Content
1. Develop systemic thinking skills through the construction of Causal Loop Diagrams (CLDs) that address the issue of urban waste overflow and its implications for global protection. (4 hours)	1. Principles of Causal Loop Diagram Construction 2. Conclusion Regarding the Threat of Urban Waste Overflow 3. Practical Application: Constructing a Causal Loop Diagram for the Threat of Urban Waste Overflow in Phitsanulok Province 4. Identification of Interconnections Among Variables and Factors Related to the Threat of Urban Waste Overflow in Phitsanulok Province
2. Protecting the world from global boiling crisis. (4 hours)	1. To synthesize the key findings and draw a comprehensive conclusion regarding the global boiling crisis. 2. To assess the inherent complexity of the global boiling threat through the identification of pertinent variables and interconnected factors, utilizing Causal Loop Diagrams (CLDs) as a systemic analytical tool. 3. To delineate the intricate interrelationships and feedback loops among the variables and factors contributing to the global boiling threat. 4. To collect comprehensive data and formulate a strategic action plan for mitigation, prioritizing the identified causal variables and factors of the global boiling threat based on their significance and impact.

Learning Units	Learning Content
	5. To strategically select and meticulously implement the proposed action plan, giving due consideration to the hierarchical importance of the variables and factors identified as primary drivers of the global boiling threat. 6. To identify and synthesize a comprehensive, holistic approach for addressing the overarching challenges posed by the global boiling threat. 7. To critically evaluate the efficacy and appropriateness of the proposed strategies or derived conclusions for ameliorating the global boiling crisis.
3. Flood crisis risk mitigation and adaptation (4 hours)	1. To synthesize the key findings and draw a comprehensive conclusion regarding the flood crisis. 2. To assess the inherent complexity of the flood crisis threat through the identification of pertinent variables and interconnected factors, utilizing Causal Loop Diagrams (CLDs) as a systemic analytical tool. 3. To delineate the intricate interrelationships and feedback loops among the variables and factors contributing to the flood crisis threat. 4. To collect comprehensive data and formulate a strategic action plan for mitigation, prioritizing the identified causal variables and factors of the flood crisis threat based on their significance and impact. 5. To strategically select and meticulously implement the proposed action plan, giving due consideration to the hierarchical importance of the variables and factors identified as primary drivers of the flood crisis threat. 6. To identify and synthesize a comprehensive, holistic approach for addressing the overarching challenges posed by the flood crisis threat. 7. To critically evaluate the efficacy and appropriateness of the proposed strategies or derived conclusions for ameliorating the flood crisis.
4. Mitigating the Global Threat of PM2.5 Dust (4 hours)	1. To synthesize the key findings and draw a comprehensive conclusion regarding the PM2.5 dust crisis. 2. To assess the inherent complexity of the PM2.5 dust crisis threat through the identification of pertinent variables and interconnected factors, utilizing Causal Loop Diagrams (CLDs) as a systemic analytical tool. 3. To delineate the intricate interrelationships and feedback loops among the variables and factors contributing to the PM2.5 dust crisis threat. 4. To collect comprehensive data and formulate a strategic action plan for mitigation, prioritizing the identified causal variables and factors of the PM2.5 dust crisis threat based on their significance and impact. 5. To strategically select and meticulously implement the proposed action plan, giving due consideration to the hierarchical importance of the variables and factors identified as primary drivers of the PM2.5 dust crisis threat. 6. To identify and synthesize a comprehensive, holistic approach for addressing the overarching challenges posed by the PM2.5 dust crisis threat. 7. To critically evaluate the efficacy and appropriateness of the proposed strategies or derived conclusions for ameliorating the PM2.5 dust crisis.
5. Safeguarding the global community from cybercrime. (4 hours)	1. To synthesize the key findings and draw a comprehensive conclusion regarding the cybercrime. 2. To assess the inherent complexity of cybercrime threat through the identification of pertinent variables and interconnected factors, utilizing Causal Loop Diagrams (CLDs) as a systemic analytical tool. 3. To delineate the intricate interrelationships and feedback loops among the variables and factors contributing to the cybercrime threat.

Learning Units	Learning Content
	4. To collect comprehensive data and formulate a strategic action plan for mitigation, prioritizing the identified causal variables and factors of the cybercrime threat based on their significance and impact. 5. To strategically select and meticulously implement the proposed action plan, giving due consideration to the hierarchical importance of the variables and factors identified as primary drivers of the cybercrime threat. 6. To identify and synthesize a comprehensive, holistic approach for addressing the overarching challenges posed by the cybercrime threat. 7. To critically evaluate the efficacy and appropriateness of the proposed strategies or derived conclusions for ameliorating the cybercrime.

Subsequently, the curriculum's suitability was assessed by subject matter experts. The evaluation yielded the following results:

Table 2. The Mean, Standard Deviation, and Appropriateness of a Protecting the World Science Club Activities Curriculum for Enhancing Complex Problem-Solving Competency asmong High School Students. (N=3)

Evaluation items	M	SD	Appropriateness Level
1. Background and Significance of the Problem			
1.1. Problem Statement and Rationale for Curriculum Development**.**	5.00	0.00	high
1. .2Clarity and Practical Implementability**.**	4.67	0.58	high
1. .3Underlying Concepts and Theoretical Frameworks**.**	4.33	0.58	high
Average	**4.60**	**0.39**	**high**
2. Principle			
2. .1Clearly define desired student attributes.	4.33	0.58	high
2. .2Promote students' complex problem-solving abilities for real-world application.	5.00	0.00	high
2. .3Ensure clarity and practical applicability.	4.33	0.58	high
2. .4Ensure appropriateness for students.	4.67	0.58	high
2. .5Align curriculum principles with complex problem resolution.	4.67	0.58	high
Average	**4.60**	**0.46**	**high**
3. Learning Outcomes			
3..1 Content demonstrates relevance to current scientific issues.	5.00	0.00	high
3..2 Content is appropriately sequenced.	4.67	0.58	high
3..3 Content is essential for students.	4.33	0.58	high
3. .4Content offers practical applicability in real-life contexts.	5.00	0.00	high
Average	**4.75**	**0.29**	**high**
4. Learning Contents			
4.1. The number of learning units is appropriate.	4.33	0.58	high
4. .2The titles of the learning units are appropriate.	4.67	0.58	high
4. .3The allocated time for each learning unit is appropriate.	4.67	0.58	high
Average	**4.56**	**0.58**	**high**
5. Curriculum Structure for Student Development Activities			
5. .1Alignment with Objectives: Activities effectively facilitate the attainment of their stated objectives.	5.00	0.00	high
5. .2Suitability for Learning Activities: The curriculum is appropriate for and complements the broader learning activities.	4.67	0.58	high
5. .3Diversity of Activities: A wide range of diverse activities are included to cater to varied interests and learning styles.	4.67	0.58	high

Evaluation items	M	SD	Appropriateness Level
5. .4Sustained Student Engagement: Activities are structured to continuously stimulate and maintain student interest throughout their participation.	4.67	0.58	high
5. .5Practical Applicability: Activities are relevant and designed in a manner that allows students to apply their learning in real-world contexts.	4.67	0.58	high
Average	**4.74**	**0.46**	**high**
6. Guidelines for Implementing Challenge-Based Learning Collaborative Systems Thinking			
6. .1There is a clear and actionable guideline for organizing activities that foster complex problem-solving competency.	4.33	0.58	high
6.2. The approach promotes challenging learning experiences and encourages students to utilize systems thinking in developing solutions.	4.33	0.58	high
6.3. The instructional approach demonstrates a high probability of achieving the curriculum's objectives.	4.33	0.58	high
6.4. The learning activities enable students to apply knowledge regarding various threats to address real-world challenges in the contemporary era.	4.33	0.58	high
6.5. The learning activities are structured as a continuous and appropriate progression of steps.	4.67	0.58	high
6.6. The challenging, collaborative, and systems-thinking-based activities actively engage students, fostering self-development and continuous learning throughout their participation.	4.67	0.58	high
6.7. Students gain knowledge through direct experiential learning.	4.67	0.58	high
6.8. Students engage in group and team-based work, fostering leadership qualities.	4.67	0.58	high
6.9. The instructional approach supports students in exploring diverse knowledge sources.	4.67	0.58	high
6.10. Students are provided opportunities to discuss and exchange knowledge with one another.	5.00	0.00	high
Average	**4.56**	**0.52**	**high**
7. Assessment and Evaluation Guidelines			
7.1. Feasibility of measurement and evaluation	4.33	0.58	high
7.2. Diversity of measurement and evaluation methods	4.33	0.58	high
7.3. Alignment of measurement and evaluation with curriculum objectives	4.33	0.58	high
7.4 .Appropriateness of evaluation criteria	4.00	1.00	high
Average	**4.24**	**0.68**	**high**
Overall Average	**3.93**	**0.40**	**high**

The evaluation results, as presented in the table, indicate that the "protecting the world science club activities curriculum", designed to enhance complex problem-solving competency among high school students, was assessed by three experts and received an overall rating of high appropriate. (M= 3.93, SD= 0.40) Upon detailed item-by-item analysis, Item 1: Background and Significance of the Problem demonstrated the highest suitability, with two sub-items rated as "high suitable" and one as "highly suitable." Item 2: Principles also exhibited strong suitability, with three sub-items assessed as "high suitable" and two as "highly suitable." Item 3: Learning Outcomes was highly appropriate, featuring four "high suitable" sub-items and one "highly suitable" sub-item. Similarly, Item 4: Learning Content showed significant appropriateness, with two "high suitable" sub-items and one "highly suitable" sub-item. Item 5: Structure of Student Development Activities Curriculum achieved complete alignment, with all five sub-items rated as "high suitable." Item 6: Guidelines for Challenge-Based Learning Collaborative Systems Thinking demonstrated exceptional suitability, with six sub-items deemed "high suitable" and four as "highly suitable." Lastly, Item 7: Guidelines for Measurement and Evaluation was entirely "highly suitable," with all four sub-items falling into this category. The overall average suitability score was 4.24. Consequently, the researcher has refined the measurement and evaluation methods to enhance clarity and detail, incorporating recommendations from expert feedback.

The research results found that the investigators studied the complex problem-solving competency of student's post-instruction using a curriculum focused on "protecting the world science club activities." This curriculum was developed to enhance complex problem-solving competency in the sample group of high school students. The results were as follows:

Table 3. The Mean, Standard Deviation, and Complex Problem-Solving Competency (N=20)

Complex Problem-Solving Competency	M	SD	Competency Level
1. Formulating the Problem Statement: Conclude or synthesize the core issue to be addressed.	4.70	0.47	high
2. Assessing Problem Complexity: Evaluate the intricacy of the problem by identifying and enumerating the relevant variables or factors contributing to it.	4.30	0.47	high
3. Establishing Interconnections of Variables: Delineate the relationships and linkages among the identified variables or factors pertinent to the problem.	4.90	0.31	high
4. Data Collection and Solution Planning: Systematically gather relevant data and formulate a comprehensive solution plan, appropriately prioritizing the causative variables or factors based on their significance.	5.00	0.00	high
5. Strategic Implementation of the Plan: Execute the formulated plan by judiciously considering and addressing the causative variables or factors in their determined order of importance.	4.70	0.47	high
6. Developing Solutions or Conclusions: Ascertain potential avenues for resolution or formulate definitive conclusions regarding effective methods for problem mitigation.	4.70	0.47	high
7. Evaluating Solution Efficacy: Appraise the suitability and effectiveness of the proposed approaches or the derived conclusions for problem resolution.	4.70	0.31	high
Overall Average	**4.71**	**0.35**	**high**

The assessment of complex problem-solving competency among high school students revealed an overall high level (M=4.71, SD=0.35). Specifically, Component 4: Information Gathering and Problem-Solving Planning, which involves appropriately collecting data and planning solutions while considering the importance of causal variables or factors in sequence, scored exceptionally high (M=5.00, SD=0.00). This proficiency in Component 4 was attributed to students' clear engagement in casual loop diagram activities. Conversely, Component 2: Problem Complexity Assessment, which involves identifying variables or factors related to the problem, yielded the lowest average score (M=4.30, SD=0.47). This lower performance is likely due to the nature of the threats students focused on, which lacked real-world exposure to actual contributing factors, potentially hindering some students' ability to clearly construct casual loop diagrams. Additionally, students had limited exposure to examples of complex innovative solutions for the threats they were interested in.

The research results found that students expressed satisfaction with the protecting the world science club activities curriculum, as evidenced by the results presented.

Table 4. The Mean, Standard Deviation, And Level of Student Satisfaction (N=20)

Evaluation Items	M	SD	Satisfaction Level
Input			
1. The instructional materials utilized by the educators in facilitating the activities effectively stimulated students' motivation to learn.	3.55	0.72	high
2. The students expressed satisfaction with the chosen venue for the activities.	3.66	0.78	high
3. The guest speakers, who provided instruction to students in programming and physics, significantly contributed to the development of students' problem-solving methodologies.	3.82	0.65	high
4. The duration allocated for each activity was deemed appropriate.	3.45	0.89	medium
Average	**3.62**	**0.76**	**high**
Process			
1. Students demonstrated significant engagement in the "Protecting the World" science club activities.	3.76	0.86	high
2. Students perceived that this activity enhanced their comprehension of environmental issues.	3.83	0.89	high
3. Students believe this club activity contributed to the development of their complex problem-solving competencies.	3.80	0.87	high
4. Student participation in this curricular activity facilitated their involvement in projects, experiments, and various activities, both within and outside of appropriate settings.	3.83	1.00	high
5. Students actively contributed to the design and planning of innovative solutions for various disaster challenges.	4.00	0.92	high
6. Students acquired novel ideas, innovations, and problem-solving approaches subsequent to their participation in the club activities.	3.90	0.92	high
7. Students expressed the opinion that this activity was beneficial for strengthening their complex problem-solving competencies.	3.93	0.88	high
Average	**3.86**	**0.90**	**high**
Output			
1. Students perceive the knowledge acquired from this club activity as suitable for practical application in daily life.	3.85	1.04	high
2. Following participation in this activity, students express an intention to adopt an attitude of heightened awareness regarding current threat issues.	3.78	0.94	high
3. Students believe this activity can contribute to solving environmental problems within their own communities.	3.85	0.99	high
4. Students consider this activity appropriate for further development and integration into science club curricula to enhance complex problem-solving competencies.	3.80	1.03	high
Average	**3.82**	**1.0**	**high**
Overall Average	**3.76**	**0.86**	**high**

The overall student satisfaction with the protecting the world science club activities curriculum, designed to enhance complex problem-solving competency for high school students, was observed to be at a high level (M=3.76, SD=0.86). A detailed analysis of the findings, categorized by input, process, and output factors, revealed several key aspects. Regarding input, students notably highlighted the benefit of specialized speakers or expert teachers invited by the instructor to provide knowledge in programming and physics, deeming this beneficial for developing their problem-solving approaches (Item 3). Concerning the process of activity implementation, students expressed a strong preference for active participation in the design or planning of innovations aimed at addressing various disaster challenges (Item 5). This was closely followed by students' perception that the activities were valuable for enhancing their complex problem-solving skills (Item 7). In terms of output, students indicated that the knowledge acquired from the club activities was highly applicable to their daily lives (Item 8). Furthermore, they believed the activities could effectively contribute to solving environmental problems within their own communities (Item 3).

5. Discussion

5.1. Investigating Global Threats and Digital Competency Development

This study explores pressing global challenges affecting Thailand with the goal of fostering complex problem-solving skills among high school students. The primary issues identified include: (1) urban waste crisis, (2) global boiling crisis, (3) frequent flooding, (4) PM 2.5 air pollution, and (5) cybercrime. Drawing on Chin-akkharawat's (2022) framework, the study evaluates the need to enhance digital competencies among secondary school teachers. Data were collected through expert interviews with educational supervisors, technology scholars, and digitally skilled teachers to gain insights into the role of digital competencies in education, obstacles to integrating digital tools into instruction, and suitable development strategies. Quantitative data from questionnaires were analyzed to determine general needs, while qualitative interviews provided nuanced understanding of key issues. This mixed-methods approach informed the design of relevant training content and learning activities to address digital threats encountered by participating educators.

5.2. Development and Validation of a Science Club Curriculum

The study developed and validated a curriculum for a "Protecting the World" science club aimed at enhancing high school students' complex problem-solving competencies. The curriculum comprises six essential elements: (1) Rationale and Significance, (2) Principles, (3) Learning Outcomes, (4) Structure of Student Development Activities, (5) Guidelines for Learning Management, and (6) Guidelines for Measurement and Evaluation. Rated as highly suitable, the curriculum aligns with Taba's (1962) model, particularly Step 1 (Content Organization Analysis) and Step 5 (Experience Selection). It also reflects Autranun's (1989) emphasis on using foundational data analysis to meet societal and learner needs. Designed with a challenge-based learning and collaborative systems thinking approach, the curriculum was reviewed by a professor and three experts in curriculum and instruction, educational evaluation, and systems thinking. Their feedback was integrated to enhance the curriculum's relevance and effectiveness.

5.3. Implementation and Evaluation of the Curriculum

The implementation of the "Protecting the World" science club curriculum demonstrated its effectiveness in improving students' complex problem-solving competencies, in line with Wonsiri's (2020) findings. Seven key components were assessed, with Component 4—"gathering information and planning solutions by prioritizing causative variables"—receiving the highest score ($M = 5.00$, $SD = 0.00$). This was attributed to student engagement in clearly structured causal loop diagram activities. However, Component 2—"assessing problem complexity by identifying relevant variables"—received the lowest score ($M = 4.30$, $SD = 0.47$), likely due to limited student exposure to real-world scenarios and a lack of examples of innovative solutions.

The findings suggest that the challenge-based collaborative systems thinking approach supports problem-solving skill development, though further enhancements are needed. Specifically, students struggled to identify emergent problems due to insufficient initial time for scenario analysis and discussion. Providing extended time, integrating real-life video clips, and facilitating model simulations improved comprehension and problem identification, consistent with Cholsin et al. (2018). Moreover, the difficulty in understanding content related to five environmental threats without direct experience contributed to lower performance in problem-solving, particularly in Component 2. This supports Lin and Chiu's (2004) assertion that deep content knowledge is essential for effective problem-solving. Thus, incorporating extended practice and technological tools can help visualize and clarify complex problems more effectively.

5.4. Student Satisfaction with the Curriculum

Students reported a high level of satisfaction with the "Protecting the World" science club curriculum, particularly regarding its role in enhancing complex problem-solving skills. This finding is consistent with Boonprakob's (2022) study, which showed high satisfaction ($M = 4.55$, $SD = 0.54$) among vocational students participating in design thinking and game-based learning to promote problem-solving. Similarly, research involving Mathayom 3 students indicated that design thinking activities fostering green innovation entrepreneurship enhanced students' engagement with social and environmental issues, encouraged the creation of green solutions, and promoted a sense of social responsibility.

6. Conclusion

The development of curriculum for instructional activities is a cornerstone of educational reform, particularly in the current context where the world faces complex and rapidly changing challenges. Therefore, research focused on developing an instructional activity curriculum grounded in Challenge-Based Learning (CBL) in conjunction with Systems Thinking is of paramount importance. This approach aims to equip upper secondary school students with enhanced competencies for higher-order complex problem-solving. The significance of such curriculum development lies in establishing a new learning paradigm. This paradigm shifts from mere content transmission to empowering students as active constructors of knowledge through engagement with authentic problems within their communities or closely related contexts. The integration of CBL principles stimulates inquiry and a commitment to seeking solutions, while Systems Thinking enables students to perceive the interconnectedness of various elements within a problem. This allows for a comprehensive analysis of causes and effects, leading to the effective formulation of alternative solutions in complex situations. Furthermore, a curriculum developed in this manner cultivates essential 21st-century skills, including collaboration, communication, critical thinking, and leadership. These are all vital attributes for self-directed progress towards goals and adaptation to lifelong learning. Curriculum development that emphasizes innovation through problem-solving also lays a crucial foundation for sustainable national and societal advancement. Learners equipped with these competencies will become a vital force in driving positive change at both local and national levels, thereby creating new economic and social opportunities for Thailand's future.

7. Recommendations

7.1. Recommendations for Research Implementation

The concluding step for problem-solving approaches should allow students ample time for internal group discussions before engaging with other groups. This strategy aims to streamline the discussion process and ensure a clear and focused scope for deliberations.

The time allocated for activity implementation should prioritize providing students with sufficient dedicated group time to highly facilitate their collaborative efforts in devising solutions and designing innovations.

When utilizing the seven-component competency assessment tool, all students should begin with a baseline score of zero. Subsequently, during the challenge-based, collaborative systems thinking instructional activities, assessment should be conducted through observation of worksheets, artefacts, and innovative products. Formative questions can be posed to inquire about problem issues, and the alignment of competency components with the teacher's questions should be carefully observed.

In the assessment of causal loop diagrams, students should be encouraged to engage in out-of-the-box thinking while remaining within the confines of the problem under investigation. The instructor must consistently monitor and provide guidance throughout the activity.

7.2. Recommendations for Future Research

Research should be conducted to develop extracurricular club curricula aimed at enhancing complex problem-solving competency related to social or natural resource issues in Thailand. Examples include curricula for "Science Strategists Clubs" or "Science Communicators Clubs," designed to broaden the dissemination of solutions by presenting them through engaging and accessible media.

Fundamental community data, including other issues, threats, and community needs related to various hazards, should be surveyed. This information should then be used to develop curricula that address community requirements and to create training programs for responding to diverse threats, tailored for other student groups or interested community members.

Systems thinking does not solely rely on the use of causal loop diagrams. Alternative methods, such as feedback diagrams, time delay diagrams, and stock and flow diagrams, can be applied to effectively address and resolve issues related to specific threats beyond the scope of this particular curriculum.

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