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Enhancing Teachers' Learning to Develop Students' 21st-Century Skills

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Abstract

his research focuses on creating a practical educational innovation designed to meet specific criteria for a defined population, facilitating broader dissemination of its results. The innovation takes the form of an online self-training program that includes two key projects: first, a self-development initiative aimed at helping teachers deepen their understanding of students' 21st-century skills; second, a project designed to enhance teachers' learning outcomes, ultimately enabling them to better cultivate these skills in their students. Employing a five-step Research and Development methodology, the study concluded with experimental research that utilized a group Pretest-Posttest design conducted in a school environment. The experimental group consisted of 14 teachers and 124 students. Results indicated that the newly developed educational innovation, titled "Online Self-Training Program for Enhancing Teachers' Learning to Develop Students' 21st-Century Skills," successfully met the quality standards proposed in the research hypothesis. These findings suggest that the educational innovation holds significant potential for nationwide implementation in schools within the targeted demographic, promoting improved teaching strategies and student outcomes across a wider educational landscape.

Keywords: enhancing the learning of teachers, 21st-century skills, students' 21st-century skills

1. Introduction

1.1 Significances of Research Problem

21st-century skills are critical tools that prepare students for global competency in an increasingly interconnected world. Students must integrate content knowledge with skills to navigate everyday challenges and succeed in their careers. This integration includes proficiency in languages and technological literacy alongside key skills such as collaboration, communication, creativity, and critical thinking. These competencies are necessary for students as they face the complexities of the 21st century (Phatinuwat, 2019).

Therefore, educational management prioritizes the development of these 21st-century skills, which can be delineated into three main categories: 1) Learning skills necessary for acquiring new knowledge; 2) Literacy skills that promote the creation and understanding of information through reading, media, and digital channels; and 3) Life skills that support individuals in everyday living (CBSE Guide, 2021).

In this context, 21st-century skills are a collection of competencies students must foster to succeed in the information age. These categories further break down into specific sub-skills: 1) Learning skills such as critical thinking, creativity, collaboration, and communication; 2) Literacy skills including information literacy, media literacy, and technology literacy; and 3) Life skills that consist of resilience, initiative, social skills, productivity, and leadership (Gill, 2022).

Education is crucial in nurturing individuals, creating communities, and building nations. It serves as the primary avenue for developing high-quality human resources that can coexist peacefully in society, especially amid the rapid transformations of the 21st century. Recognizing the importance of 21st-century skills, various stakeholders have made strategic recommendations to facilitate their development. For instance, Oxford University Press ELT (2013) suggested five key strategies: 1. Allow students to lead their learning; 2. Create an inquiry-based classroom environment; 3. Foster collaboration; 4. Develop critical thinking skills; and 5. Encourage creativity. Shaikh (2019) also offered ten strategies: 1. Implement individual, pair, and group tasks, projects, and activities; 2. Engage in peer teaching and reviews; 3. Use presentations with PowerPoints, audiovisual materials, and handouts; 4.

Conduct role plays; 5. Administer surveys and other data collection techniques; 6. Promote reading, research, and reference activities; 7. Utilize graphic organizers and prompts; 8. Negotiate essential agreements; 9. Mentor fellow learners; and 10. Carry out assessments for learning.

Recognizing the importance of 21st-century skills, many educators and institutions have shown interest in proposing innovative methods to enhance these competencies. Our research team explored perspectives from various academic and educational organizations regarding this matter. The investigation uncovered valuable insights from numerous scholars and educational entities, mainly expressed in scholarly articles. These articles clarify the definition of 21st-century skills, their characteristics, strategies for development, recognized developmental steps, challenges faced, ways to tackle these challenges, and assessment methods to evaluate individual proficiency in these skills. It's worth noting that quantitative research often overlooks such qualitative insights, which typically focus on various factors or indicators. Moreover, textbooks both in Thailand and internationally usually need to better align with current 21st-century educational perspectives.

Our research underscores the significance of utilizing knowledge from articles written by verified, reliable sources such as university lecturers, school teachers, educational administrators, researchers, and practitioners. This article aims to provide insights tailored to creating practical learning modules for our research. This aligns with Sanrattana's (2023) point on the importance of harnessing contemporary knowledge from diverse credible viewpoints to design these modules. Ultimately, this methodology promotes the professional development of educators, enabling them to implement the learning outcomes with their students effectively.

1.2 Research Objective

This research focuses on developing educational innovations through the Research and Development (R&D) methodology to achieve effective outcomes that meet specified criteria. The results of this research are intended for a target group that can apply them for broader dissemination. The educational innovation takes the form of an online self-training program consisting of two key projects: 1) A self-development project for teachers to learn about the 21st-century skills of their students and 2) A project aimed at helping teachers implement learning outcomes to further develop these 21st-century skills in their students. The aim is to strengthen teachers' knowledge and skills, enabling them to enhance their students' learning experiences significantly.

1.3 Research Hypothesis

This research used the Research and Development (R&D) method to create educational tools that apply current knowledge for the 21st century. The team worked with trustworthy people and organizations to put together Learning Modules aimed at helping teachers improve and then allowing them to pass those skills on to their students.

The project followed a specific approach, R1D1 ... RiDi, which has been effective in previous studies. For example, researchers like Kratumnok and Phrakhrusutheejariyawattana (2024) looked into "Empowering Teachers' Learning to Strengthen Students' Teamwork Skills." Others, like Suchato and Phrakhrusutheejariyawattana (2024), focused on enhancing teachers' skills to promote prosocial behavior in students, while Nukoonkan and Dhammapissamai (2023) developed strategies to improve teachers' project management skills for their students. All these studies showed that their educational innovations worked based on their research hypotheses.

As a result, this study set up two main hypotheses: 1) After running the experiment in the R5D5 phase of the "Teachers' Learning Development Project on Students' 21st Century Skills," it was expected that the teachers in the experimental group would score above the set standard of 90/90 on their post-tests, significantly improving from their pre-test scores. 2) It was also anticipated that after the same phase in the "Teachers' Learning Outcomes Development Project on Students' 21st-Century Skills," the students in the experimental group would assess their 21st-century skills significantly higher than before the experiment.

1.4 Literature Review

Our research focuses on the knowledge from various academic articles and educational institutions distributed online globally. The reviewed articles provide valuable insights for creating learning modules to advance students' 21st-century skills. We explored expert perspectives from different regions through articles on several topics:

1) Definition of Students' 21st-Century Skills: Views from Buckle (n.d.), CBSE guide (2021), Gill (2022), The Great Schools Partnership (2016), and Thoughtful Learning (n.d.).
2) Approaches to Developing Students' 21st-Century Skills: Insights from Dimitriadis (n.d.), Nurture (n.d.), Oxford University Press ELT (2013), Potter (2021), Rap (2022), Roslaniec (2018), Shaikh (2019), and

Thomas (2018).

3) Process of Developing 21st-Century Skills: Contributions from Admin (2019), Esters (2021), Geus (2017), Lee (n.d.), and Willis (n.d.).
4) Challenges in Developing 21st-Century Skills: Perspectives from Challenges (2021), Doskocil (2016), Dussault (2018), and Gamalearn (n.d.).
5) Overcoming Challenges: Strategies from Bates & Exell (2022), Coombs (2021), and Green (2022).
6) Assessing 21st-Century Skills: Insights from Abdallah (n.d.), Han & Sung (2019), Kelley, Knowles, Teach Thought Staff (n.d.), Kharbach (2019), The University of Maine (n.d.), and Wiggers (n.d.).

Through this literature review, developing learning modules for teachers based on these topics will equip them with comprehensive knowledge. This knowledge will allow them to teach and support their students effectively. The "development approaches" section is particularly crucial, offering diverse methods and techniques for fostering 21st-century skills. While some strategies may be familiar to confident educators, many will introduce innovative alternatives suited to contemporary educational demands, offering teachers fresh insights into skill development in the 21st century.

Therefore, we synthesized the "development approaches" from the study of the perspectives of Dimitriadis (n.d.), Nurture (n.d.), Oxford University Press ELT (2013), Potter (2021), Rap (2022), Roslaniec (2018), Shaikh (2019), and Thomas (2018). The following 33 approaches emerged:

1) Let your students lead the learning
2) Create an inquiry-based classroom environment
3) Encourage collaboration
4) Develop critical thinking skills
5) Foster creativity and imagination
6) Enhance communication skills
7) Cultivate analytical thinking
8) Implement individual, pair, and group tasks, projects, and activities
9) Utilize peer teaching and reviewing
10) Encourage presentations using PowerPoints, audiovisuals, and handouts
11) Incorporate enactment in learning activities
12) Use questionnaires, surveys, and other data collection methods
13) Apply graphic organizers and prompts
14) Negotiate essential agreements among students
15) Provide mentorship for other learners
16) Promote self-assessment and feedback
17) Encourage independence in learning
18) Facilitate discussions
19) Engage in project-based learning (PBL)
20) Develop information literacy
21) Advanced media literacy
22) Promote technology literacy
23) Enhance digital literacy
24) Foster adaptability
25) Encourage leadership skills
26) Stimulate initiative among students
27) Improve problem-solving efficiency
28) Teach manners and politeness

29) Instill kindness

30) Promote collaboration for mutual benefits

31) Cultivate global and cultural awareness

32) Encourage resilience

33) Support creativity in problem-solving

These approaches serve as essential strategies for enhancing the development of 21st-century skills among students.

2. Research Methods

2.1 Concepts and Processes

This research employed the Research and Development (R&D) Methodology to create an online self-training program based on the hypothesis. Inspired by Sanrattana (2023), it aimed to provide up-to-date knowledge from credible sources to develop teachers. The focus was on enabling teachers to learn and then apply their knowledge with students, reflecting the principle that "Knowledge and Action are Power" rather than the earlier concept of "Knowledge is Power." The research steps in the R1D1… RiDi format was outlined as follows:

R1D1 Process: This initial step involved a comprehensive literature review on students' 21st-century skills. The topics explored included: 1) Definition: Understanding what constitutes 21st-century skills. 2) Development Approach: Investigating effective methods for cultivating these skills. 3) Development Process: Examining the stages involved in skill development. 4) Challenges and Obstacles: Identifying potential barriers to successful implementation. 5) Ways to Overcome Challenges and Obstacles: Developing strategies to address these issues. 6) Evaluation: Assessing the effectiveness of current approaches.

Each topic was discussed through credible articles authored by recognized experts, leading to the creation of six learning modules within the online self-training program. This foundation prepared teachers to enhance their understanding of and ability to develop these crucial skills in their students, drawing from the perspectives outlined by Sanrattana (2023).

The R2D2 process has culminated in the development of an extensive program aimed at significantly enhancing teacher training and fostering students' essential 21st-century skills. This innovative program is structured around two fundamental initiatives: the "Online Self-Training Program for Enhancing Teachers' Learning to Develop Students' 21st-Century Skills."

The first initiative, the Teacher Learning Development Project, offers a meticulously designed suite of self-learning modules firmly grounded in thorough research and literature reviews. These modules explore a range of critical topics that are vital for educators in today's rapidly evolving educational landscape, including:

- *Definition of 21st-Century Skills:* This section explores the various competencies that constitute 21st-century skills. It emphasizes the importance of critical thinking, collaboration among peers, creativity in problem-solving, and digital literacy, all of which are pivotal for students' success in a technology-driven world.

- *Approaches to Skill Development*: This section introduces a selection of pedagogical strategies to assist teachers in seamlessly integrating skill development into their existing curricula. These include project-based learning, inquiry-based approaches, and collaborative group work, all of which promote active engagement and deeper understanding.

- *Processes Involved*: This paper comprehensively examines the different frameworks and methodologies educators can adopt to effectively implement these essential skills in their classrooms, giving teachers various lenses through which to approach their instruction.

- *Challenges Faced:* This section identifies and critically analyzes potential obstacles that teachers may encounter as they strive to implement these skills. It addresses issues such as student resistance, curriculum constraints, and a lack of resources.

- *Strategies to Overcome Challenges*: Teachers are provided with practical solutions and best practices that have been proven effective in overcoming these obstacles, thus facilitating a smoother implementation process.

- *Assessment Methods*: This part offers detailed guidelines on various assessment techniques that educators can use to evaluate their students' proficiency in these 21st-century skills. These techniques allow for ongoing feedback and adaptation of teaching methods.

Six carefully structured self-learning modules are available, allowing teachers to engage with the material at their

own pace, which promotes independent learning. Each module is designed with a clear organizational framework, presenting content in Thai alongside links to the original English versions, ensuring accessibility for a wider audience. Interspersed questions encourage teachers to continuously assess their understanding, adhering to principles of learning psychology. An engaging activity is embedded within the modules, requiring teachers to answer targeted questions that evaluate their knowledge and teaching experiences.

The second initiative, termed the Teachers Leading Learning Outcomes to Development Project, is focused explicitly on actively promoting the acquisition of 21st-century skills among students. This comprehensive work manual contains several key components meant to provide teachers with a robust framework

1) *Instruction:* Clear and structured guidance is offered to help teachers implement the curriculum effectively, ensuring that all learners can engage with the material meaningfully.
2) *Summary of Expected Characteristics*: This section outlines a detailed description of the specific student competencies that should be targeted, giving teachers a clear vision of the skills they aim to cultivate.
3) *Development Guidelines*: Best practices and principles are presented to foster these skills within classroom settings, providing teachers with actionable steps to create an environment conducive to skill development.
4) *Overview of the Development Process*: This guide provides a step-by-step breakdown of how to implement various teaching strategies effectively, ensuring that teachers feel confident in their instructional practices.
5) *Questionnaire for Assessing Students' 21st-Century Skills:* This well-structured tool allows teachers to assess their students' current level of proficiency in 21st-century skills, allowing for data-driven insights into student performance.
6) *Self-Assessment Form for Teachers:* This Google Form serves as a reflective practice tool for teachers, enabling them to evaluate their adherence to the development guidelines and identify areas for improvement.
7) *Teachers' Self-Assessment on Development Model Selection:* Another Google Form is included to assist teachers in reflecting on their choice of development process models. This ensures that the selected model aligns with their teaching context and objectives.
8) *Self-Reflection Form for Teachers:* This Google Form encourages educators to reflect critically on their teaching practices, promoting a continuous cycle of improvement and professional development.

This comprehensive methodology aims to enhance teacher development and emphasize the practical application of students' 21st-century skills within educational environments, ultimately benefiting student learning outcomes.

To deepen understanding, teachers are encouraged to refer to the specific presentation format outlined in each learning module available at http://www.mbuisc.ac.th/phd/Module9/Supatta.pdf. This format includes detailed content structure guidelines that cover objectives, key concepts, interactive elements, and assessment criteria, ensuring a well-rounded and inclusive learning experience. Additionally, an accompanying diagram visually represents this framework, illustrating the interconnected nature of these initiatives and the program's intended outcomes.

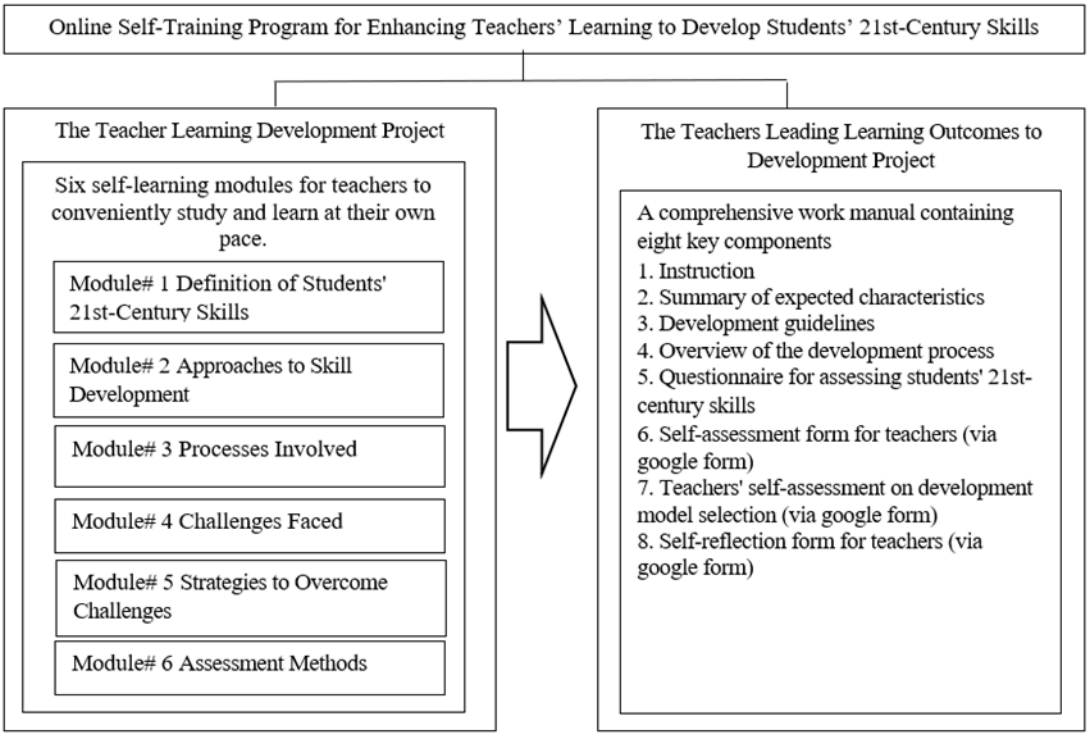

Figure 1. Online self-training program for enhancing teachers' learning to develop students' 21st-century skills

R3D3 Process: This phase involved verifying the appropriateness of the program's content. Focus Group Discussions were conducted in two phases:

- Preliminary Field Testing and Revision: Engaged five teachers to gather initial feedback.

- Main Field Testing and Revision: Expanded to ten teachers for a deeper assessment.

R4D4 Process: During this stage, two sets of assessment instruments were created for the experimental research: 1) A test measuring teacher learning outcome and 2) An assessment tool for evaluating students' 21st-century skills. Please see the detailed description in the "Research Tools" section.

R5D5 Process: This final step involved testing the effectiveness of the online self-training program through experimental research using a One Group Pretest-Posttest Design. This study was conducted in a purposively selected school, with an experimental group of 14 teachers and 124 students during the second semester of 2024. The research was split into two phases:

Phase 1 Experimental research on the development project for teacher learning. This document addresses the stage of self-development for teachers participating as the experimental group within Project 1. The teachers will engage in self-training utilizing the Learning Modules from Project 1 and the Work Manual from Project 2, designed to be accessed online. The primary objective is to evaluate whether implementing these Learning Modules and the Work Manual results in the teachers achieving specified learning outcomes that align with the 90/90 standard or whether their outcomes post-experiment demonstrate a statistically significant improvement compared to their performance before the experiment. The subsequent section details the activities and duration of the implementation of this developmental project aimed at enhancing the teachers' learning, as shown in Table 1.

Table 1. Activities and duration of the development project for teachers' learning

Activity	Duration
1. Introduce the research operation to the teachers in the experimental group and administer the developed teacher learning outcome test as a pre-test to assess their initial knowledge and competencies.	2 days
2. Facilitate teacher development through self-training based on learning units and project manuals available for download from the university website, encouraging self-directed learning.	30 days
3. Have the teachers in the experimental group collaboratively evaluate the quality of the learning units and project manuals. Then, follow up with a post-test using the developed teacher learning outcome test to measure progress.	2 days
4. Analyze and compare the teacher test results post-experiment against the 90/90 standard criteria, evaluating learning outcomes before and after the intervention to determine the program's effectiveness.	2 days

Phase 2: Experimental research on the project of teachers bringing learning outcomes into practice for students. This stage focuses on the application of learning outcomes in practice for the teachers in the experimental group. They work together to implement the insights from self-development through the Learning Modules (Project 1) and the Work Manual (Project 2), developed online to meet the desired developmental goals. The objective is to evaluate whether the teachers in the experimental group can effectively translate these learning outcomes into practice, aiming for significant improvements in their results after the experiment compared to before. The activities involved and their corresponding durations are detailed in Table 2, which outlines the project timeline for teachers to apply these learning outcomes with their students.

Table 2. Outlines the activities and duration of the project focused on teachers applying learning outcomes in practice for students

Activity	Duration
1. Pre-Test Assessment: Teachers in the experimental group will be informed about the research operations. They will evaluate the students using the developed assessment form to establish a baseline measure of student performance.	2 days
2. Implementation of Learning Outcomes: The teachers will implement learning outcomes in practice by diligently following the guidelines provided in the work manual.	60 days
3. Post-Test Assessment: After applying the learning outcomes, the teachers will collaboratively review both the quality of the learning units and their work manuals from the two projects. They will then evaluate the students again using the same assessment form, marking this as a post-test assessment.	2 days
4. Data Analysis: Finally, a comparative analysis will be conducted on the students' evaluation results to assess the effectiveness of the implemented strategies before and after the experiment.	2 days

2.2 Research Tools

The Teacher Learning Outcome Test was strategically designed as a four-choice multiple-choice assessment to evaluate teachers' learning outcomes during the critical pre- and post-experimental stages. This test is structured according to the Cognitive Domain of learning, following the well-established hierarchy of Bloom's Taxonomy as revised by Krathwohl in 2002. It encompasses the essential levels of remembering, understanding, applying, analyzing, evaluating, and creating.

A robust two-phase validation process was implemented to ensure the highest quality and effectiveness of the test. In the first phase, we rigorously assessed the test's content validity using the Indexes of Item-Objective Congruence (IOC) methodology proposed by Rovinelli and Hambleton (1977), backed by expert evaluations from five seasoned educational professionals. Our analysis confirmed that all test questions were suitable and ideally aligned with the intended measurement objectives, as evidenced by IOC values exceeding the critical threshold of 0.50 (Chaichanawirote & Vantum, 2017).

In the second phase, we conducted a pilot test, administering the full assessment to 30 teachers from a distinct school not involved in the experimental group. Our data analysis revealed several compelling findings:

1) Every question fell well within the acceptable Index of Difficulty range of 0.20 to 0.80, demonstrating appropriate levels of challenge.
2) The Power of Discrimination for each question met and exceeded established criteria, ranging from 0.20 to 1.00, affirming the test's effectiveness in differentiating between various levels of teacher performance.
3) The KR-20 reliability coefficient achieved an impressive 0.93, far surpassing the acceptable benchmark of

0.70, underscoring the test's exceptional reliability.

4) The overall difficulty index of the test stood at 55.36, indicating a well-calibrated level of challenge for the participants.

These compelling results demonstrate that the Teacher Learning Outcome Test is valid and reliable, making it an outstanding tool for measuring teachers' educational outcomes within the framework of this study.

The Assessment of Students' 21st-Century Skills. In this research, utilizing a self-assessment questionnaire to investigate 21st-century skills has illustrated numerous compelling advantages. Highlighting these benefits may improve our understanding of how self-assessment can positively impact learning outcomes and skill development.

1) *Personal Insight*: One of the significant benefits of self-assessment questionnaires is promoting personal insight among learners. According to Zimmerman (2002), self-regulation in learning is enhanced by individuals' ability to assess their understanding and skills. By engaging in self-assessment, learners gain a clearer perspective on their strengths and weaknesses, which is crucial for targeted skill development. This reflective practice facilitates a deeper understanding of one's learning journey and encourages autonomy in educational pursuits.

2) *Cost-Effective Approach*: Self-assessment questionnaires represent a highly cost-effective approach to evaluating 21st-century skills. Dawson (2010) argues that standardized assessments often require substantial financial resources for development, administration, and analysis. In contrast, self-assessment questionnaires can be designed and deployed with minimal costs, making them accessible to a broader range of educational institutions. This economic advantage enables organizations to allocate resources to other essential areas, such as curriculum development and instructional materials.

3) *Easy Accessibility:* Self-assessment questionnaires are often easily accessible, enabling users to participate anytime and anywhere. McDonald, Ransom, and Campbell (2015) note that the advent of digital platforms allows for the widespread distribution of self-assessment tools, reaching diverse populations beyond the traditional classroom setting. This accessibility enhances participation rates and ensures that learners from various backgrounds can engage with the tools, fostering inclusivity in skill assessment.

4) *Fostering Ownership of Learning*: When learners engage in self-assessment, they cultivate a sense of ownership over their educational process. Hattie and Timperley (2007) highlight that ownership is critical for motivation and learner engagement. By allowing individuals to evaluate their competencies and set personal learning goals, self-assessment encourages learners to take responsibility for their educational outcomes. This empowerment can lead to more proactive learning behaviors as students seek out opportunities for further development based on their self-reflections.

5) *Promoting Reflection*: Self-assessment inherently promotes reflective practices essential for meaningful learning experiences. Pickard (2019) asserts that Reflection helps learners internalize knowledge and critically evaluate their learning strategies. Self-assessment can stimulate intellectual curiosity and self-improvement by prompting individuals to think deeply about their skills and learning processes. This reflective component is vital for fostering lifelong learning habits, as it encourages continuous assessment and adaptation of skills over time.

In conclusion, using self-assessment questionnaires to investigate 21st-century skills offers significant advantages, including enhanced personal insight, cost-effectiveness, easy accessibility, fostered ownership of learning, and the promotion of reflective practices. These benefits collectively contribute to more meaningful and compelling learning experiences, emphasizing the need for incorporating self-assessment tools in educational settings.

The self-assessment questionnaire utilized a 5-level rating scale: strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree. This self-assessment was developed based on a review of the literature regarding the characteristics of students' 21st-century skills, drawing insights from works by Oxford University Press ELT (2013), Roslaniec (2018), Thomas (2018), Shaikh (2019), Potter (2021), Rap (2022), Dimitriadis (n.d.), and Nurture (n.d.). Additionally, the literature on the assessment of these skills was informed by research from Kharbach (2014), Kelley, Knowles, Han & Sung (2019), Abdallah (n.d.), Teach Thought Staff (n.d.), The University of Maine (n.d.), and Wiggers (n.d.).

From the results of developing this self-assessment questionnaire, we have defined the framework of 21st-century skills expected of students, including the focus on teachers' teaching, focusing on six key variables that outline the essential characteristics expected from teachers and students. Accompanying each variable are specific indicators and assessment questions:

1) Self-Awareness: seven indicators and seven questions
2) Problem-Solving Skills: seven indicators and seven questions
3) Resilience and Grit: five indicators and five questions
4) Analytical Skills and Logical Thinking Skills: six indicators and six questions
5) Creative Thinking and Entrepreneurial Mindset: five indicators and five questions
6) Digital Fluency and Technology Fluency: five indicators and five questions

Further details can be found in Table 4.

Five educational experts evaluated the assessment for quality in two phases. In Phase 1, the content validity was checked, and the data analysis revealed that all questions had an Item Objective Congruence (IOC) value exceeding the 0.50 criterion, indicating their suitability for the intended purpose.

Phase 2 involved checking the reliability or internal consistency of the assessment, which was conducted with 30 students from a school outside the experimental area. The analysis found that the assessment's overall Alpha Coefficient of Reliability was 0.78. When examining each aspect of the assessment, the reliability values were as follows: self-awareness (0.77), problem-solving skills (0.80), resilience and grit (0.78), analytical and logical thinking skills (0.87), creative thinking and entrepreneurial mindset (0.80), and digital fluency and technology fluency (0.71). These values surpassed the acceptable threshold of 0.70 (George & Mallery, 2003).

2.3 Data Analysis

1) For the standard criteria of 90/90, data were analyzed as defined by Yamkasikorn (2008). The formula used to calculate the first 90 = {(Σ X /N) X 100)}/R where the first 90 numbers mean the percentage of the average score of the post-test. Σ X means the total score of the test results that each learner did correctly on the post-test. N means the total number of learners used as the sample to calculate efficiency this time. R means the full score of the post-test. The formula used to calculate the last 90 numbers = (Y x 100)/N, where the previous 90 numbers mean the percentage of learners who can pass all test objectives. Y means the number of learners who can pass all test objectives. N means the total number of learners used as the sample to calculate efficiency this time.

2) Mean scores from pre-and post-tests were compared using the dependent t-test. The calculation formula is as follows:

$$t = \frac{\sum D}{\sqrt{\frac{n\sum D^2 - (\sum D)^2}{(n-1)}}}$$

∑D means the sum of the differences between the scores before and after the development.

∑D2 means the sum of the differences between the scores before and after the development squared.

N means the total number of students who have been developed.

3. Research Results

As mentioned earlier, this research used R&D methodology that emphasized "Bringing up-to-date knowledge for the 21st century from various perspectives of reliable individuals or organizations to create Learning Modules to develop teachers to learn first, and then apply the learning outcomes to practice with students" with the research steps in the Form of R1D1…. RiDi. It created a belief that this research will result in practical educational innovations. The results of the research found that the research results were in line with the specified research hypothesis, as follows.

3.1 Results of Testing the Research Hypothesis No. 1

After the experimental research under the self-development project for teachers focusing on students' 21st-century skills in the R5D5 step, 14 teachers in the experimental group underwent the "Teacher Learning Outcome Test" to assess their learning results. The findings revealed that 1) the experimental group of teachers achieved an average score on the post-experiment test of 33.21 points, which represented 89.48 percent of the total possible score of 36 points, meeting the first 90 standard criteria, and 2) One hundred percent of the teachers in this group were able to successfully pass the test by all objectives, adhering to the last 90 standard criteria as well.

Furthermore, when comparing the average scores from the teacher learning outcome test conducted before and after the experiment, it was noted that the teachers had an average pre-experiment test score of 22.43 with a standard deviation of 4.16, while the average score post-experiment was 33.64 with a standard deviation of 3.00. A

dependent t-test indicated that the post-experiment scores were significantly higher than the pre-experiment scores at the 0.05 level, as shown in Table 3.

Table 3. Compare pre- and post-experiment test scores from the teacher learning outcome test using a dependent samples t-test

Testing	Sample size	Mean	Standard Deviation	t
Before	14	22.43	4.16	8.97*
After	14	33.64	3.00	

*Significant at ($p<0.05$).

The results of the hypothesis testing, including the comparisons made with the 90/90 standard and the pre-and post-experiment test scores, demonstrate that the "Teachers' Self-Development Project for Learning about Students' 21st-Century Skills" developed through this research process is efficient enough for dissemination and practical application in educational settings. This indicates that the project effectively enhances teachers' capabilities in fostering 21st-century skills among their students.

3.2 Results of Testing the Research Hypothesis No. 2

After the experimental research aligned with the project aimed at enhancing students' 21st-century skills through the R5D5 step, 124 students from the experimental group evaluated their self-assessed levels of 21st-century skills using the "Students' 21st-Century Skills Assessment Form." This evaluation was conducted to determine the effectiveness of the educational innovation that had been developed. Before and after the experiment, the results are presented in Table 4, highlighting overall performance and breakdown by each specific aspect of the skills assessed.

Table 4. Mean and standard deviation value of students' 21st-century skills assessment results before and after the experiment, overall and classified by each aspect

Students' 21st-Century Skills Expected to Occur in Research.	Assessment Results			
	Before		After	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Self-Awareness	2.65	0.24	3.57	0.67
1. I am aware of my ability to transfer my skills.	3.16	0.71	3.25	0.77
2. I am aware of my ability to convey my knowledge.	2.59	0.49	2.85	0.87
3. I am aware of and understand my strengths and weaknesses or areas for growth.	2.39	0.49	2.90	1.10
4. I am aware of my courage to challenge my own cultural biases.	2.44	0.50	3.68	1.32
5. I am aware of the limitations of design and know when to consider alternatives.)	2.65	0.48	3.88	1.21
6. I am aware of my courage to challenge my own cultural biases.	2.62	0.49	4.15	1.17
7. I know different perspectives and ideas and make decisions impartially.	2.73	0.56	4.30	1.12
Problem-Solving Skills	2.98	0.35	4.60	0.69
8. I can clearly define the problem.	2.84	0.48	4.33	1.09
9. I can clearly explain the nature of the problem.	2.83	0.44	4.50	0.90
10. I can solve problems without the help of others.	2.95	0.52	4.58	0.88
11. I can resolve conflicts in the workplace.	2.83	0.70	4.55	1.03
12. I can offer assistance to others when needed.	3.42	0.56	4.73	0.67
13. I can evaluate alternatives to propose solutions and define outcomes as possible solutions.	2.93	0.65	4.73	0.76
14. I can use the suggestions to improve my work.	3.03	0.71	4.77	0.71
Resilience and Grit	2.81	0.30	4.69	0.72
15. I can be physically and mentally prepared each day.	2.60	0.49	4.68	0.84
16. I can tolerate the new changes well.	2.73	0.58	4.72	0.79
17. I can be flexible to suit the needs.	2.98	0.57	4.67	0.80
18. I can be open-minded and respond to others' creative ideas.	2.82	0.46	4.71	0.80
19. I can develop the ability to adapt to changing environments.	2.94	0.63	4.66	0.87
Analytical Skills and Logical Thinking Skills	2.92	0.25	4.63	0.72
20. I can analyze data to summarize findings.	2.88	0.45	4.68	0.76
21. I can synthesize information and be creative.	3.31	0.68	4.77	0.60
22. I can think and assess the quality of data comprehensively.	2.84	0.52	4.62	0.83
23. I can think critically and logically.	2.78	0.47	4.59	0.86
24. I can present creative ideas, take a stand, and compellingly articulate problems.	3.07	0.57	4.62	0.82
25. I can adjust evaluation criteria appropriately.	2.64	0.55	4.53	0.98
Creative Thinking and Entrepreneurial Mindset	2.82	0.24	4.44	0.76
26. I support the use of creative and imaginative ideas.	2.79	0.51	4.70	0.74
27. I support creative brainstorming and original ideas.	2.76	0.43	4.58	0.88
28. I support unique and innovative products.	3.13	0.53	4.50	0.85
29. I encourage a growth mindset to break free from my comfort zone and try new things.	2.48	0.50	4.30	1.18
30. I support exploring new sources of information and inspiration when no one else can.	2.97	0.46	4.11	1.05
Digital Fluency and Technology Fluency	2.83	0.26	3.33	0.77
31. I support adapting to new things and emerging technologies.	2.65	0.48	3.56	1.24
32. I support the effective use of online tools and software.	2.94	0.51	3.40	0.97
33. I support the systematic development of technology plans.	3.16	0.58	3.64	0.97
34. I support safe settings and professional social media usage.	2.67	0.68	3.05	1.07
35. I support directing students to record and reflect on their learning outcomes.	2.75	0.50	2.98	0.79
Total	**2.85**	**0.18**	**4.20**	**0.54**

Table 4 shows the results of the assessment of characteristics showing 21st-century skills of students. The overall average score of the evaluation before the experiment was equal to 2.85 with a standard deviation of 0.18, while the average score from the assessment after the experiment was equal to 4.20 with a standard deviation of 0.54. When analyzed using a dependent t-test, it was found that the evaluation scores after the experiment were significantly higher than before at a statistical level of 0.05, as shown in the data analysis results in Table 5.

Table 5. Comparative analysis of the mean scores from the assessment of 21st-century skills of students before and after the experiment using a dependent t-test

Evaluating	Sample size	Mean	Standard Deviation	t
Before	124	2.85	0.18	30.36*
After	124	4.20	0.54	

*Significant at ($p<0.05$).

The findings from the comparative analysis of students' mean self-assessment scores, presented in Table 5, indicate that the "Teachers Applying Learning Outcomes to Practice with Students" project has proven effective. This success suggests the project is ripe for dissemination among the intended audience.

When we take a broader view, it becomes clear that the "Online Self-Training Program" encompasses two distinct but interrelated initiatives: 1) the Teachers' Self-Development Project, which aims to enhance educators' understanding of students' 21st-century skills, and 2) the Teachers' Learning Outcomes initiative, designed to empower educators in fostering these critical skills among their students. This dual approach represents a significant and quality educational innovation with the potential for widespread implementation within the target demographic.

The credibility of this innovation stems from its foundation in research and development (R&D) methodology. This approach's principle is that any educational innovation should be rigorously tested. The results of these experiments demonstrate that the innovation not only meets the established criteria for effectiveness but also possesses the potential for meaningful integration and dissemination within the communities involved in the research.

4. Discussion

Buckle (n.d.) outlines 21st-century skills as essential competencies that include knowledge, crucial life skills, career-focused abilities, and essential traits vital for a student's success in our fast-changing world. As students transition to higher education and the workforce, these skills become increasingly important, enabling them to handle adult responsibilities more effectively. While aspects like critical thinking, collaboration, and problem-solving have been part of educational curricula for years, the shifting economic landscape has made it even more urgent for schools to adopt these skills in a structured way. As a result, many school districts are now incorporating 21st-century skills into their teaching agendas to prepare students for future challenges better.

The core aim of our research was to innovate educational practices using a research and development (R&D) approach. This led to creating an online self-training program that includes two main projects. The first project equips educators with strategies to nurture and develop their students' 21st-century skills. In contrast, the second project offers teachers methods to effectively apply learning outcomes, thus enhancing students' competencies even further.

Our research indicates that the "Online Self-Training Program for Enhancing Teachers' Learning to Develop Students' 21st-Century Skills" has been effective and meets our initial criteria. This program is well-suited for widespread use, allowing for increased access and implementation in various educational settings.

We owe many of our insights to reliable articles from academic and educational organizations and key references in our study involving university lecturers, school teachers, educational administrators, and field workers. This information is incredibly relevant in our current knowledge-driven society, which emphasizes the sharing and usage of knowledge for the benefit of its people (Rahman, 2009). With the internet playing a crucial role in disseminating contemporary knowledge globally, it's essential for advancing learning and research initiatives.

Bastis Consultores (2021) highlights numerous advantages of leveraging the internet, from quick and affordable information sharing to extensive knowledge access and efficient communication. These benefits are critical for educators striving to stay updated and effective in their teaching methods.

Our research team also conducted an extensive review that looked at various global perspectives on 21st-century skills. This review delved into essential topics such as definitions, development paths, developmental stages, challenges, barriers, and assessment tools. By transforming these insights into actionable learning modules, we can better empower teachers through online self-training, giving them the comprehensive understanding they need to tackle these critical issues in their classrooms.

Our findings particularly focused on "development approaches," which provide educators with various principles, concepts, techniques, methods, and activities to enhance students' skills. We identified 33 distinct approaches from

scholars worldwide, emphasizing practical frameworks that extend beyond what traditional textbooks often offer.

Notably, we recognized a significant gap in the available resources; many textbooks present a broad overview without diving into the depth that teachers need. Similarly, existing research often zeroes in on specific variables, which can fall short of fulfilling broader educational objectives. By bridging these gaps, our proposed learning modules can enrich professional development and improve teaching practices that cultivate 21st-century skills.

As we navigate this terrain, it's important to remember a few key considerations about our study's limitations and biases. For example, the focus on developing an online self-training program may not cover the full range of 21st-century skills or various educational contexts.

Additionally, while our participant base did include teachers, it may not represent the broader educational landscape, which could skew our findings. We also have to be cautious of biases like selection bias—which can arise from the self-selected nature of participants—or confirmation bias, which might lead us to overlook less favorable or contrary evidence in our results.

In conclusion, while our research provides valuable insights into how we can enhance 21st-century skills through targeted teacher training, it's vital to approach the findings with careful consideration of their limitations, the potential cultural biases, and how they might be adapted or applied in diverse educational settings. By doing so, we can work toward maximizing the impact of our initiatives and ensuring effective learning for all students.

5. Conclusion

This research has successfully developed an online self-training program titled "Online Self-Training Program for Enhancing Teachers' Learning to Develop Students' 21st-Century Skills." The program effectively meets established criteria and reinforces the research hypothesis, demonstrating its value to the intended audience.

The initiative's success is informed by various academic sources highlighting the importance of equipping individuals with knowledge to improve workforce effectiveness. Key studies underline this program's relevance: Kratumnok and Phrakhrusutheejariyawattana (2024) emphasize teamwork development in students, while Suchato and Phrakhrusutheejariyawattana (2024) focus on fostering prosocial behavior. Nukoonkan and Dhammapissamai (2023) address enhancing project management skills, demonstrating the program's significance.

The online self-training specifically targets challenges teachers face in nurturing 21st-century skills among students. It provides practical strategies to develop problem-solving, creativity, and technology fluency while presenting effective classroom implementation methods.

Adaptable across diverse educational settings, the program draws from 33 global approaches and fills gaps left by traditional resources. It recognizes difficulties like heavy workloads and limited time and comprehensively identifies issues related to promoting 21st-century skills.

To enhance the practical application, we offer constructive recommendations:

1) Professional Development Workshops for time management.
2) Collaborative Planning Time to foster teamwork.
3) Streamlined Administrative Processes to reduce paperwork.
4) Student Support Systems for peer collaboration.
5) Flexible Curriculum Design to cater to student interests.
6) Parental Engagement Strategies to Strengthen Support.
7) Mental Health and Wellness Support to reduce burnout.
8) Feedback Loops for teacher input on improvements.

By addressing these challenges, the online self-training program equips educators with essential tools and strategies to create supportive learning environments, ultimately fostering 21st-century skills and enhancing academic performance.

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Authors contributions

Supatta Om-On, a doctoral candidate in Educational Administration, is entrusted with conducting rigorous independent research, upholding the highest ethical standards, preparing a scholarly dissertation, and strictly adhering to all established deadlines throughout the process. Wirot Sanrattana and Phrasrivajiravati, serving as the dissertation advisors, are charged with providing comprehensive guidance, constructive critique, mentorship, and academic oversight to facilitate Supatta Om-On's progress and ensure success from initial topic selection through to dissertation completion and graduation.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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