Integrating Open Educational Resources with Design Thinking: An Instructional Design Model for Enhancing Innovator Competencies

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***Abstract*—Innovator competencies are crucial for preparing learners to thrive in today's rapidly evolving world by fostering creativity, openness, and the ability to connect ideas for innovation. This study developed an instructional design model integrating Open Educational Resources (OER) with Design Thinking (DT) to enhance these competencies, focusing on the post-COVID-19 context. The research followed three phases: developing the model, creating the OER-Innovator System, and implementing the model experimentally. The study involved 312 lower secondary students from five pilot schools in the Central Lower Region of Thailand, selected through purposive sampling. The model consists of seven components, including instructor's role, learner's role, learning content, teaching methods, learning activities, learning resources and assessment and evaluation, organized into an eight-step instructional process. Results showed a statistically significant improvement in students' knowledge of DT and innovation ($p < 0.01$). Furthermore, students' innovation projects and innovator competencies were rated at good levels, demonstrating significant achievement. The analysis also revealed a positive relationship between students' innovation project outcomes and their innovator competencies, indicating that stronger competencies contribute to better project performance. Expert validation confirmed the model's appropriateness and effectiveness in promoting student-centered learning and innovation. These findings highlight the potential of this integrated approach to bridge educational gaps, foster lifelong learning, and support educational innovation in the post-pandemic landscape.**

***Keywords*—instructional design, Open Educational Resources (OER), Design Thinking (DT), innovator competencies**

I. Introduction

In today's rapidly advancing world, cultivating innovator competencies such as creativity, critical thinking, and problem-solving has become essential for preparing learners to meet the complexities of the 21st century. These skills enable students to develop innovative solutions, bridge ideas across disciplines, and adapt to the swift changes in technology and society [1, 2]. Innovator competencies are particularly crucial in promoting lifelong learning, which is vital for personal and professional growth and for addressing complex global challenges [3].

However, the COVID-19 pandemic has severely disrupted educational systems worldwide, including Thailand [4]. The sudden closure of schools necessitated a rapid shift from in-person learning to online platforms. While online education ensured continuity, it presented significant challenges. Many Thai students, especially those from underprivileged backgrounds, lacked access to essential technology such as computers and stable internet connections [5]. This digital divide, combined with the limitations of remote learning, such as reduced peer interaction, excessive screen time, and the inability of online tools to fully replicate in-class experiences, resulted in significant learning loss. Consequently, this setback hindered students' mastery of core subjects and development of critical innovator competencies, exacerbating existing educational inequalities [6].

Before the pandemic, students actively developed innovator competencies through collaborative classroom activities and project-based learning. These hands-on experiences were instrumental in fostering creativity, problem-solving, and the ability to produce innovative outcomes [7]. However, the shift to online learning during the pandemic significantly reduced opportunities for collaborative and experiential activities, disrupting the development of these competencies [8]. Consequently, gaps in students' skills and understanding emerged, particularly in their capacity to engage in innovative processes effectively. Upon returning to traditional learning environments post-COVID-19, students often lacked the confidence and capability required for innovation, highlighting the urgent need for targeted educational strategies to address these deficiencies [9, 10].

Given this context, it is imperative for teachers to design learning experiences that can bridge these gaps and help students recover lost competencies. However, traditional teaching models are often insufficient for fostering the kind of dynamic, student-centered learning required to develop innovator competencies. Integrating DT and Open Educational Resources (OER) emerges as a key strategy for overcoming these challenges. DT, a human-centered problem-solving approach, fosters creativity, empathy, and iterative thinking key components of innovator competencies [1]. By engaging students in the process of ideation, prototyping, and testing, DT not only enhances problem-solving skills but also encourages students to take an active role in their own learning, making it a powerful tool in education [3].

At the same time, OER provides flexible, freely accessible educational content that can be tailored to diverse learning contexts and student needs [11]. The adaptability of OER allows teachers to personalize learning materials, making them more relevant and engaging for students. When integrated with DT, OER serves as a valuable resource for creating interactive, learner-centered environments that promote hands-on learning and real-world problem-solving [12].

By integrating DT with OER, teachers can address the limitations of traditional instruction and online learning, bridging the gaps created by the pandemic. This innovative approach equips educators to design engaging, student-centered learning experiences that not only mitigate learning loss but also foster the development of essential innovator competencies. Ultimately, this model reimagines classrooms as dynamic environments where students gain the skills needed to navigate a rapidly changing world, solve complex problems, and drive societal and technological advancements.

II. Research Objectives

The objectives of this research are as follows:

1) To develop an instructional design model using open educational resources integrated with design thinking to enhance innovator competencies.
2) To develop open educational resources system integrated with design thinking to enhance innovator competencies.
3) To study the results of implementing an instructional design model.

III. Literature Review

This study synthesized key components of instructional design models, OER, DT, and innovator competencies to provide guidelines and strategies for enhancing learners' competencies.

A. Instructional Design Model

Instructional design models offer essential frameworks for creating structured and effective learning experiences, whether in traditional or digital environments. Among these, the ADDIE (Analyze, Design, Develop, Implement, Evaluate) model is one of the most flexible and widely used, particularly in online learning, where continuous refinement is crucial [13]. The Gerlach and Ely Model has also proven influential, focusing on media integration and clear instructional objectives, making it highly suitable for technology-supported classrooms [14]. Instructional design, as a systematic process, involves the stages of analysis, design, development, implementation, and evaluation to solve educational problems and enhance learners' understanding [15].

The Kemp Model, characterized by its iterative and non-linear approach, allows educators to continuously revisit various instructional elements, ensuring adaptability in changing educational contexts [16]. Similarly, the ASSURE Model [17] provides a process for integrating technology into instruction, promoting active learner engagement and effective media use.

In higher education, the Dick and Carey Systems Approach Model breaks down instruction into manageable units, emphasizing alignment with learning objectives, which is particularly useful for online education [18]. Furthermore, in the Thai context, scholars such as Khammani have contributed models that focus on contextually relevant and learner-centered approaches, reflecting the specific educational needs of Thailand [19].

In conclusion, these instructional design models provide robust frameworks that help educators create adaptable and effective learning experiences whether applied individually or in combination across various educational contexts.

B. Open Educational Resources (OER)

OER are transformative tools that reduce educational costs and expand global access to quality learning materials. UNESCO [20] defines OER as teaching, learning, and research materials shared under open licenses, allowing no-cost access, reuse, revision, remix, and redistribution. These resources empower educators and learners to modify and share content freely. Wiley [21] emphasizes their role in fostering equity and inclusive education, while Cozart *et al*. [22] highlight their ability to alleviate students' financial burdens without compromising learning quality.

The "5Rs" framework, detailed by Wiley [21] and Tlili *et al*. [23], encapsulates OER's core attributes: reuse, allowing materials to be used across contexts without alteration; revise, enabling adaptation to specific needs; remix, combining resources with new content for customization; redistribute, sharing resources in original or modified forms; and retain, granting users long-term ownership and control. These features make OER a cornerstone of equitable and sustainable education.

OER offer substantial benefits. Tlili *et al*. [23] highlight their support for lifelong learning by enabling context-specific adaptations and enhancing pedagogy. Cozart *et al*. [22] found that students value OER for their affordability and flexibility compared to traditional textbooks. Fischer *et al*. [24] demonstrate that students using OER perform as well as or better than peers using traditional materials, underscoring their potential to improve educational outcomes. Otto [25] suggests that the institutional integration of OER can address educational inequalities by expanding access to quality resources. However, challenges remain, including barriers such as limited awareness, insufficient infrastructure, and concerns about resource quality.

In conclusion, OER effectively reduce educational inequities and costs through their flexible "5Rs" framework. Addressing challenges such as awareness, infrastructure, and localization is essential for their widespread application. Future research should focus on these areas to maximize OER's impact in diverse educational contexts.

C. Design Thinking (DT)

DT has emerged as a powerful approach for fostering innovation, particularly in educational and professional settings. DT encourages creative problem-solving by emphasizing empathy, ideation, prototyping, and testing. Originally popularized by Tim Brown and Nigel Cross, the approach has been widely adopted in various fields, including education, healthcare, and business [26, 27].

In education, DT is recognized for cultivating innovator competencies such as creativity, critical thinking, collaboration, and experimentation. Carroll *et al*. [28] demonstrated that DT engages students in iterative problem-solving processes, enhancing their skills and fostering a mindset of continuous improvement essential for innovation. Koh *et al*. [29] further highlighted DT's role in Science, Technology, Engineering and Mathematics (STEM) education, where it encourages critical thinking and hands-on application of theoretical knowledge, bridging the gap between learning and practice.

The five iterative stages of DT include Empathize, Define,

Ideate, Prototype, and Test, serving as a structured framework that encourages students to immerse themselves in the learning process [30]. The process begins with Empathize, where designers engage with users to deeply understand their needs and challenges, thereby laying the foundation for identifying the correct problem to address [31, 32]. In the Define stage, the information collected is synthesized into a clear problem statement, which guides the development of targeted solutions [32]. The Ideate phase encourages the generation of multiple potential solutions through brainstorming, fostering creativity and innovation. During the Prototype stage, designers create scaled-down versions of solutions, allowing for hands-on testing of their practicality in real-world scenarios. Finally, the Test stage gathers user feedback to refine and improve the solutions, ensuring they meet real needs. This iterative approach makes DT adaptable across various fields, as it allows solutions to evolve based on continuous user feedback [33]

The role of DT in building soft skills is also notable, particularly in fostering collaboration, communication, and empathy. Studies by Canina and Bruno [34] show that students who engage in DT develop essential interpersonal skills that enhance their ability to work in interdisciplinary teams and contribute creatively to group projects. These competencies are vital for success in both educational and professional environments, where teamwork and innovation are increasingly prioritized.

In conclusion, DT plays a crucial role in fostering innovator competencies, including creativity, critical thinking, and collaborative problem-solving. By engaging students in a human-centered, iterative process, DT equips them with the skills necessary for innovation in a rapidly evolving world.

D. Innovator Competencies

Innovator competencies refer to the essential skills that enable individuals to generate new ideas, solve complex problems, and contribute to innovation. These competencies include creativity, critical thinking, adaptability, collaboration, and the ability to implement novel solutions effectively. Developing these skills is crucial not only in professional settings but also in educational contexts, where students must be prepared to meet the demands of an evolving world [35]. In education, project-based and problem-based learning environments play a significant role in nurturing these skills, encouraging students to engage with real-world problems and collaborate across disciplines [36].

Digital innovator competency includes skills such as creative thinking, problem-solving, and digital literacy [30]. Integrating these into curricula is challenging, as traditional assessments often overlook complex skills like adaptability and creativity. Innovative and flexible assessment methods are essential to measure these competencies effectively [37]. Educational institutions must adapt to foster and evaluate these skills, equipping students to succeed in a rapidly evolving world.

The researcher synthesized innovator competencies by integrating theoretical and empirical findings, defining key elements for skill development and providing a structured framework for assessment, as presented in Table 1.

Table 1. The synthesis of innovator competencies

Innovator Competencies	Dyer, Gregersen and Christensen [35]	Chaemchoy [38]	Schilling [39]	Manuel, Monica and Juan [40]	Kiattikan *et al.* [41]	Schindel *et al.* [42]	Sue Buck [43]	Butter and Beest [44]	Conclusion
Questioning	√	√				√	√		√
Initiative								√	
Apophenia		√							
Pursuing Multiple Streams		√							
Observing	√	√	√		√	√	√		√
Obsessive Notetaking		√							
Individual Competencies				√					
Technical Knowledge					√				
Creativity								√	
Critical Thinking								√	
Networking	√	√	√	√		√	√	√	√
Resource Management			√						
Teamwork				√				√	
Experimenting	√	√	√				√		√
Associating	√		√		√	√	√		√
Innovative Entrepreneurial Leadership		√							

Based on the synthesis, innovator competencies are defined as five key components: Questioning, Observing, Networking, Experimenting, and Associating. Questioning involves challenging assumptions to explore new possibilities. Observing focuses on uncovering hidden opportunities through the analysis of behaviors and trends. Networking enhances problem-solving by integrating diverse perspectives. Experimenting refers to refining ideas through iterative trial and error. Associating connects seemingly unrelated concepts to spark innovative breakthroughs, collectively forming a comprehensive framework for fostering innovation.

IV. Materials and Methods

A. Research Samples

The research sample consisted of 30 teachers from pilot schools in the Central Lower Region of Thailand, selected using a multistage sampling process: (1) simple random sampling to identify three provinces; (2) purposive sampling to choose five schools implementing innovative teaching and learning methods; and (3) purposive sampling to select teachers specializing in innovation education. Additionally, 312 lower secondary students from the same five pilot schools were selected through purposive sampling from the schools where the participating teachers were involved in the research. Signed informed assent forms were obtained from the participants and their guardians, providing consent for their participation in the study.

B. Research Methodology

The research process is divided into four phases as follows:

1) Phase 1: developing an instructional design model

This phase focuses on reviewing, analyzing, and synthesizing relevant literature and research to identify key components that contribute to effective instructional design. By studying academic sources and established frameworks, this step aims to extract essential principles that define impactful teaching practices. The outcome will form a solid foundation for developing a new instructional design model that meets current educational demands.

The researcher examined the challenges and needs in teaching and learning, specifically addressing student competencies and attributes in schools in the Central Lower Region of Thailand. A focus group was convened to identify strategies for developing an instructional design model. This group consisted of 10 experts in instructional design, educational technology, and learning design, along with key stakeholders in the regional education system. These participants, selected through purposive sampling, collaborated to propose solutions, plan strategies, and establish guidelines for the development of the instructional design model.

2) Phase 2: developing OER integrated with DT to enhance innovator competencies (OER-innovator system)

This research focuses on developing an OER-Innovator System that integrates OER with DT to enhance innovator competencies. The system development follows the Systems Development Life Cycle (SDLC) [45], structured into five steps:

1) Requirement Analysis: This step involves studying existing educational challenges and identifying system requirements, particularly for students, teachers, and system technology. Key needs include easy access to OER, tools for innovation skill development, and a collaborative environment that supports both learning and teaching processes.
2) System Design: Based on the requirements, the system architecture is designed to ensure flexibility and scalability. The design includes modules for OER management, learning design, innovator competency development, and assessment and evaluation. It also ensures responsiveness across devices and scalability for future expansion.
3) System Development: In this phase, the platform is built and configured with the necessary tools to support interactive content creation, collaboration, and assessment functionalities.
4) Testing: The system underwent unit, integration, system, and acceptance testing to ensure stability and functionality. A quality assessment was conducted by nine experts specializing in content, instructional design, and technical aspects, all with at least three years of professional experience. The system's efficiency was further evaluated using the E1/E2 performance criteria with students prior to implementation.
5) System Launch: After successful testing, the system is launched for use by students and teachers. Ongoing maintenance includes regular updates, data backups, and technical support.

3) Phase 3: The study on the effects of using an instructional design model

The study on the effects of using an instructional design model and the OER-Innovator System is detailed as follows:

1) Pre-Experimental Planning: This phase involved coordinating with schools and teachers across seven provinces to implement the learning model. Preparations included setting up OER materials, DT tools, and developing guides and assessments such as knowledge tests, competency rubrics, and satisfaction surveys.
2) Implementation: Workshops were conducted to train 30 teachers in using the learning model. Teachers designed and implemented activities based on OER and DT principles. Students' DT knowledge was assessed before and after the learning process, while their innovator competencies were evaluated only after the learning process. Their innovation projects were also assessed to measure progress. The implementation phase with students was conducted over six weeks.
3) Data Collection: Data were collected through pre and post-tests on students' knowledge of DT, competency rubrics for assessing innovator competencies, and evaluations of students' innovation projects. Additionally, satisfaction surveys gathered student feedback on the learning experience. These multiple sources of data helped provide a comprehensive view of the learning model's impact.
4) Data Analysis: The collected data were analyzed using t-tests to compare students' knowledge before and after the intervention. Innovator competencies and innovation projects were assessed through rubrics, and student satisfaction was analyzed using mean and standard deviation to evaluate the effectiveness of the instructional design model. Additionally, Pearson's correlation coefficient was used to determine whether there is a relationship between students' innovator competencies and their innovation project outcomes.

V. Result

The research findings are presented as follows:

A. Instructional Design Model Using OER Integrated with DT to Enhance Innovator Competencies

The instructional design model consists of three key

components: (1) the elements of the instructional design model, (2) the process of instructional design using OER, and (3) the implementation of the instructional design model. The following sections provide diagrams and detailed explanations of each component, as illustrated in Fig. 1.

1) The elements of the instructional design model

The instructional design model is composed of seven key elements:

a) Instructor's role

Instructors act as facilitators, designing lessons with a focus on design thinking principles. They guide activities, create a conducive learning environment, provide appropriate resources, encourage collaboration, and evaluate student progress to foster innovator competencies. Facilitators also offer continuous support, give constructive feedback, assist students in applying knowledge to real-world problems, and provide guidance in creating innovative projects, ensuring an engaging and practical learning experience.

b) Learner's role

Students actively engage in the learning process by participating in activities, problem-solving, and collaboration. They practice critical thinking, teamwork, and apply design thinking to create innovative solutions.

c) Learning content

This includes content on innovation, types of innovations, development processes, and characteristics of innovators. The goal is to enable students to grasp key concepts and apply them in real-world contexts.

d) Teaching methods

Teaching integrates the stages of design thinking, such as empathy, problem definition, idea generation, prototyping, and testing. This approach promotes creative thinking and problem-solving skills, encouraging students to develop practical solutions.

e) Learning activities

These include individual and group projects, promoting brainstorming, problem analysis, and multi-perspective discussions based on design thinking principles.

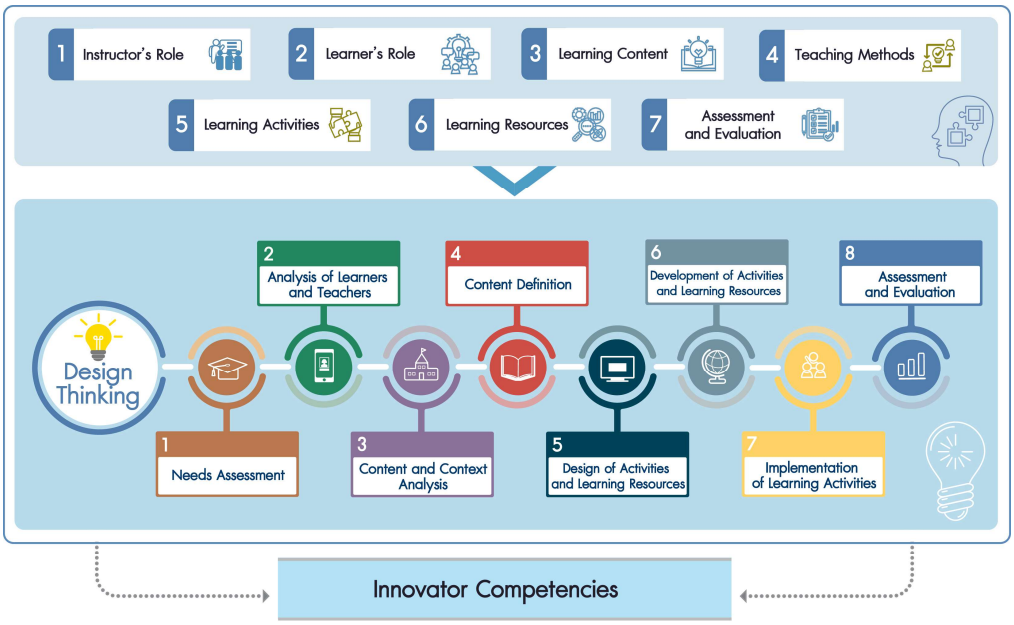

Fig. 1. Instructional design model using open educational resources integrated with design thinking to enhance innovator competencies.

f) Learning resources

OER-based platforms provide access to high-quality educational resources such as videos, articles, and multimedia. These open resources facilitate learning and support students in developing their innovator competencies anytime, anywhere.

g) Assessment and evaluation

The evaluation focuses on measuring the learning process, knowledge in design thinking, innovation outcomes, and innovator competencies. Rubrics are used to assess projects and ensure the application of learned skills in solving real-world problems.

2) Steps in the instructional design model integrating OER with DT

The instructional design model consists of eight structured steps:

a) Needs assessment

This step identifies the learning needs and contextualizes teaching strategies to align with subject-specific goals. It includes an analysis of both learners' needs and course objectives to ensure the instructional model matches the intended outcomes.

b) Analysis of learners and teachers

Instructors conduct a detailed assessment of learners' knowledge, skills, and behaviors. This stage ensures the instructional design considers the learners' strengths, challenges, and the teachers' instructional capacity to effectively facilitate design thinking processes.

c) Content and context analysis

This step evaluates the relevance of the course content to real-world challenges. It integrates learning environments that promote creativity, and problem-solving within both face-to-face and online settings.

d) Content definition

Learning content is aligned with the instructional goals by incorporating topics related to innovation creation, collaboration, and design thinking, ensuring a strong foundation for developing innovator competencies.

e) Design of activities and learning resources

Activities are integrated with design thinking principles, promoting collaboration, creativity, and hands-on experimentation. The materials align with learning objectives and encourage students to develop innovative solutions, applying empathy, ideation, prototyping, and testing throughout the process. OER provides accessible tools to enhance learning and support the practical application of innovative thinking.

f) Development of activities and learning resources

Learning materials, such as multimedia content, interactive elements, and self-directed learning platforms, are prepared. Support systems are designed to offer seamless access to learning resources in both physical and online environments

g) Implementation of learning activities

This step involves delivering lessons based on the design thinking framework. Instructors facilitate interactive activities, guiding students through iterative problem-solving processes to apply their innovative ideas.

h) Assessment and evaluation

Student outcomes are evaluated using rubrics to assess their innovation projects and innovator competencies. Formative and summative assessments are used to monitor progress and ensure alignment with learning objectives, fostering continuous improvement.

3) The implementation of the instructional design model

The implementation focuses on key aspects. Instructors must be proficient in using OER, online tools, and DT, designing activities to enhance innovator competencies while mentoring students and tracking their progress. Learners participate in collaborative projects, hands-on activities, and self-assessments using design thinking. Constraints include the model's suitability for project-based education, emphasizing practical methods and authentic assessments focused on innovation and problem-solving.

Table 2. The results of the quality assessment of the instructional design model

Assessment Criteria	Assessment Results		Quality Levels
	$\bar{x}$	S.D.	
Elements of the Instructional Design Model	4.74	0.44	Highest
Steps in the Instructional Design Model Integrating OER with DT	4.75	0.44	Highest
Implementation of the Model	4.77	0.43	Highest
Overall Quality	**4.75**	**0.44**	**Highest**

The evaluation of the instructional design model was conducted by 10 experts. These specialists, with expertise in instructional design, educational technology, design thinking, and innovator competencies, assessed the model's quality. Their feedback and assessment results are summarized in Table 2.

The overall quality of the model was rated at 4.75 (S.D. 0.44), confirming that the model consistently achieved the highest level of quality across all evaluated areas.

B. OER-Innovator System

The OER-Innovator System, available at www.oerinnovation.com, has been developed and implemented with three primary components: instructor functions, learner functions, and system administration functions. This web-based platform provides teachers with resources on design thinking, innovation development, and instructional design, enabling them to study and understand these concepts in depth and apply them to enhance their teaching practices. At the same time, the platform allows students to explore these principles as a framework for developing their own innovations. A variety of resources, including infographics and videos, are offered to ensure the content is accessible, engaging, and easy to comprehend. An example of the system interface is shown in Fig. 2.

1) Instructor functions

The system supports teachers in integrating OER and DT principles into their teaching strategies. It provides access to relevant content, such as innovation concepts and competencies, and facilitates the design of activities that foster creativity and problem-solving. Instructors can also provide learning resources.

2) Learner functions

Students access OER materials recommended by instructors to study DT processes and innovation principles. They engage in project-based activities that involve hands-on practice, collaboration, and self-assessment.

3) Administrative functions

The administrative tools manage user accounts, access roles, and the content within the system. This includes adding, updating, or removing learning materials and ensuring continuous system performance through regular maintenance and data backups. Administrators also handle user support and monitor storage to accommodate the growing needs of uploaded content and student projects.

This OER-Innovator System ensures accessible learning through responsive web design that is compatible with various devices, such as smartphones, tablets, and computers. It offers a structured approach to teaching and learning, enhancing innovator competencies and problem-solving skills, with continuous support from instructors and administrators.

Table 3. Content quality evaluation of the OER-innovator system

Assessment Criteria	Assessment Results		Quality Level
	$\bar{x}$	S.D.	
1. Content and Presentation	4.60	0.63	Very High
2. Appropriateness of Language and Illustrations	4.73	0.56	Very High
3. Relevance of Content to Typography and Colors	4.63	0.49	Very High
4. Alignment of Content with OER and DT	4.53	0.52	Very High
Overall Content Quality of the System	**4.62**	**0.55**	**Very High**

The content quality of the OER-Innovator System, evaluated by content experts, was rated at the very high level overall ($\bar{x}$ = 4.62, S.D. = 0.55), as presented in Table 3.

The instructional design quality of the OER-Innovator System, evaluated by instructional design experts, was rated

at the very high level overall ($\bar{x}$ = 4.65, S.D. = 0.53), as presented in Table 4.

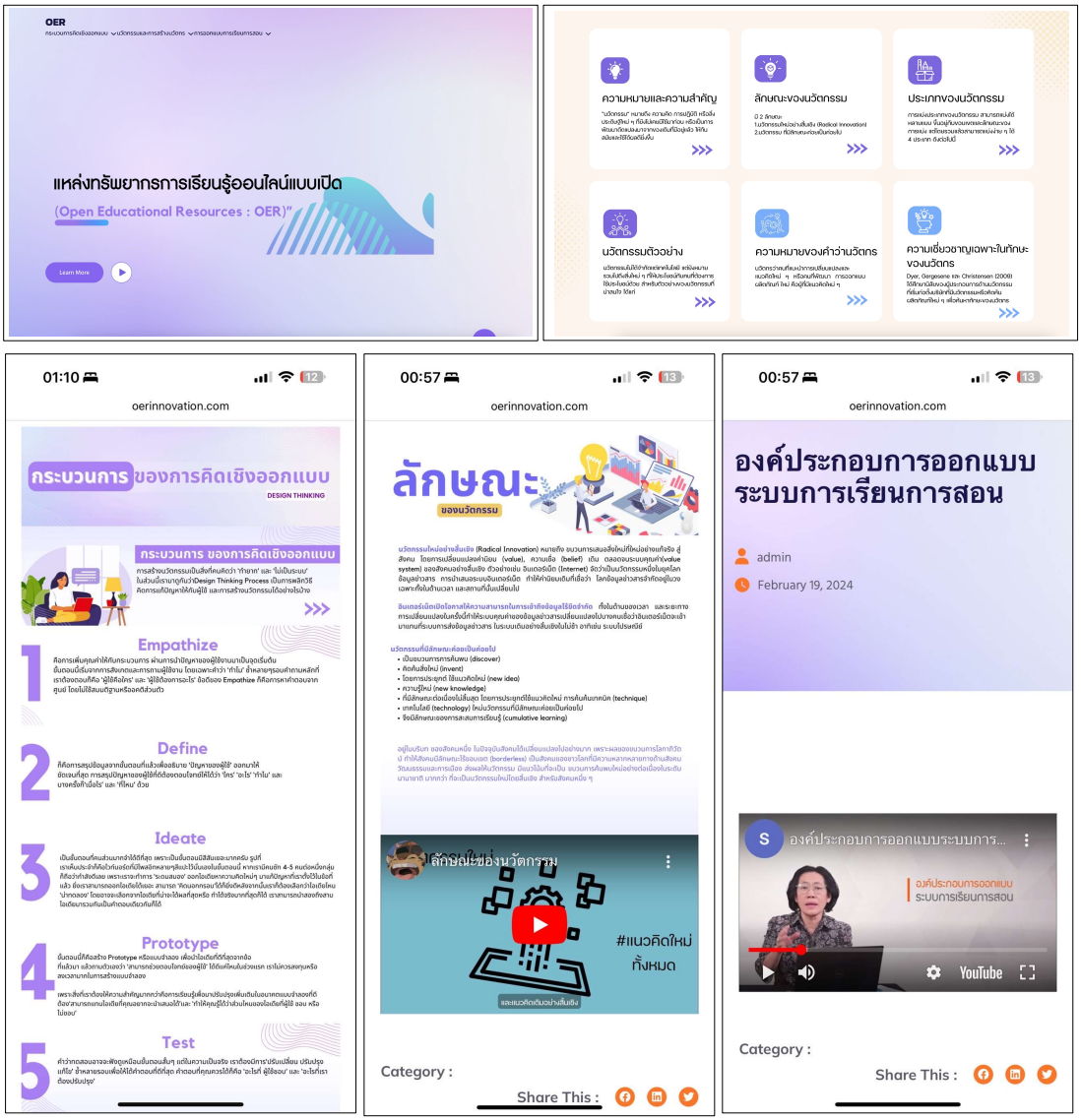

Fig. 2. Open educational resources integrated with design thinking to enhance innovator competencies (OER-innovator system).

Table 4. Instructional design quality evaluation of the OER-innovator system

Assessment Criteria	Assessment Results		Quality Level
	$\bar{x}$	S.D.	
1. Design of Learning Resources	4.68	0.54	Very High
2. Design of Learning Activities	4.51	0.65	Very High
3. Design of OER with DT to Develop Innovator Competencies	4.57	0.57	Very High
Overall Instructional Design Quality of the System	**4.65**	**0.53**	**Very High**

Table 5. Technical quality evaluation of the OER-innovator system

Assessment Criteria	Assessment Results		Quality Level
	$\bar{x}$	S.D.	
1. System Capability	4.71	0.67	Very High
2. Functionality	4.63	0.59	Very High
3. Usability	4.56	0.58	Very High
4. Security	4.53	0.51	Very High
5. Performance Efficiency	4.66	0.65	Very High
Overall Technical Quality of the System	**4.62**	**0.60**	**Very High**

The technical quality of the OER-Innovator System, evaluated by technical experts, was rated at the very high level overall ($\bar{x}$ = 4.62, S.D. = 0.60), as presented in Table 5.

The result of the effectiveness assessment (E1/E2) from students who tested the system prior to actual implementation was 83.12/85.53, which met the set criteria of 80/80.

C. Results of Implementing the Instructional Design Model Integrating OER with DT

This study evaluated the implementation of an instructional design model. Teachers employed the model to create subject-specific learning activities and materials. The trial involved 312 students from pilot schools across in the central region of Thailand. The data analysis is organized into four sections.

1) Comparison of students' knowledge scores

This study compares students' knowledge scores of design thinking and innovation creation before and after learning, as shown in Table 6. A paired t-test revealed a significant improvement ($t = -43.68$, $p < 0.01$), with post-learning scores averaging 29.89 out of 40, compared to 14.75 before the implementation.

Table 6. Comparison of students' scores before and after the implementation of the model

Design Thinking and Innovation Creation Knowledge Scores	n	$\bar{x}$	S.D.	t-test	*p*-value
Before Learning	312	14.75	4.98	−43.68**	0.00
After Learning	312	29.89	3.82		

**$p < 0.01$

2) Results of students' innovation projects post-implementation

The students' innovation projects were assessed post-implementation using a three-level rubric. Teachers conducted the assessments, and the results are summarized as follows in Table 7.

Table 7. Results of students' innovation project assessment post-implementation

Assessment Criteria	Assessment Results		Innovation Project Level
	$\bar{x}$	S.D.	
1. Creativity and Novelty	2.44	0.62	Good
2. Feasibility of Implementation	2.40	0.57	Good
3. Impact on Users and Society	2.25	0.69	Good
4. Effectiveness	2.27	0.61	Good
5. Acceptance and Scalability	2.13	0.67	Good
Overall Innovation Project Level	**2.30**	**0.64**	**Good**

The overall assessment of students' innovation projects post-implementation shows that the projects were rated at a "Good" level ($\bar{x}$ = 2.30, S.D. = 0.64).

3) Results of students' innovator competencies post-implementation

The students' innovator competencies were assessed post-implementation using a three-level rubric focused on five dimensions: questioning, observation, networking, experimentation, and associating. Teachers conducted the assessments, and the results are summarized as follows in Table 8.

The assessment results presented in Table 8 indicate that students achieved a well-rounded level of innovator competencies post-implementation. Competencies in questioning, observation, networking, and associating were evaluated as "Good" with experimentation receiving the highest rating of "Very Good" The overall competency level ($\bar{x}$ = 2.35, S.D. = 0.60) reflects a solid development across all areas, highlighting experimentation as a key strength within the model. The findings indicate that the instructional design model successfully enhanced core competencies essential for innovation.

Table 8. Results of students' innovator competencies assessment post-implementation

Assessment Criteria	Assessment Results		Innovator Competencies Level
	$\bar{x}$	S.D.	
1. Questioning	2.42	0.59	Good
2. Observation	2.32	0.57	Good
3. Networking	2.20	0.66	Good
4. Experimentation	2.51	0.53	Very Good
5. Associating	2.28	0.61	Good
Overall Innovator Competencies Level	**2.35**	**0.60**	**Good**

4) Results of the study on the relationship between innovation projects and innovator competencies

The researcher analyzed the relationship between Innovator Competencies and Innovation Projects by examining the direction of the relationship through a scatter plot. This analysis aimed to determine the correlation between Innovator Competencies scores and Innovation Projects scores, which were derived from authentic student assessments using a rubric scoring method. The results of the scatter plot are presented in Fig. 3.

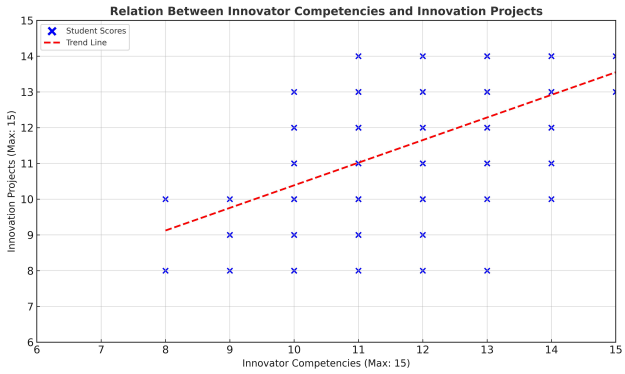

Fig. 3. Relationship between innovator competencies and innovation projects.

Fig. 3 illustrates that Innovator Competencies and Innovation Projects exhibit a positive correlation. This finding suggests that as Innovator Competencies increase or decrease, Innovation Projects scores tend to increase or decrease accordingly.

Following a preliminary analysis using a scatter plot, the researcher conducted a further examination of the relationship between Innovator Competencies and Innovation Projects using Pearson's Product-Moment Correlation Coefficient. The analysis revealed a Pearson correlation coefficient of 0.56, which is statistically significant at the 0.01 level ($r = 0.56$, $p < 0.01$). These results indicate that as the scores for innovator competencies increase, the outcomes of innovation projects tend to improve correspondingly. Conversely, when the outcomes of innovation projects improve, the scores for innovator competencies are also likely to increase.

5) Results of students' satisfaction post-implementation

The student satisfaction assessment following the implementation of the instructional design model reveals a highest level of satisfaction ($\bar{x}$ = 4.51, S.D. = 0.68). The top three areas of satisfaction are: students felt the activities improved their ability to become innovators, students appreciated having direct access to OER, and students reported enhanced learning about innovation development through the activities. These results suggest that the model effectively supports innovative learning and self-directed engagement, especially in the post-COVID-19 context.

6) Results of the instructional design model expansion

The researcher expanded the instructional design model and OER implementation to additional areas and schools within the Central Lower Region, involving 291 elementary students. The findings indicate that students' post-test scores in design thinking and innovation were significantly higher than their pre-test scores, with a statistical significance level of 0.01. Students' innovation projects were evaluated as being of good quality, and their innovator competencies also showed good performance following the model's application.

Furthermore, students reported high satisfaction with the learning activities, reflecting their positive experience with the model.

VI. Discussions

The findings demonstrate that the model achieved high ratings across seven key components: the roles of teachers and learners, learning content, teaching methods, learning activities, learning resources, and assessment. These components work cohesively to create an effective system for promoting innovation and adaptability in post-pandemic learning environments. A key component is the role of teachers as facilitators, designing lessons grounded in DT principles. They create activities that foster engaging learning environments, provide appropriate resources, and guide students in applying knowledge effectively, ensuring continuous support throughout the process. This shift reflects the evolving responsibilities of teachers, as highlighted by Beijaard *et al*. [46], and underscores the significance of data-informed practices in addressing learners' needs, as emphasized by Datnow and Park [47].

The role of learners is pivotal, as research indicates that active engagement in the learning process significantly enhances its effectiveness. DT fosters systematic problem-solving by encouraging learners to experiment, iterate, and develop new ideas, enabling them to construct knowledge independently. Additionally, the utilization of OER as primary learning materials provides learners with unrestricted access to knowledge, promoting diverse and flexible learning experiences tailored to individual needs and capabilities. Research by Bond *et al*. [48] supports the effectiveness of OER-based learning in fostering critical thinking, collaboration, and creative problem-solving. Li [49] further noted that learner-centered tasks enhance students' analytical skills and motivation for self-directed learning. The integration of OER materials relevant to real-world challenges ensures that learning remains both practical and innovative. Saçak *et al*. [50] found that well-structured content promotes deeper engagement.

Experiential teaching methods within the model enhance students' problem-solving abilities by offering real-life scenarios. Novo *et al*. [51] found that hands-on learning through DT develops critical 21st-century competencies like creativity and teamwork. The learning activities further promote collaboration, critical thinking, and innovation through group projects and interactive tasks. Halverson *et al*. [52] noted that combining technology with teamwork increases student engagement and learning outcomes.

Learning resources play a pivotal role in the learning model, with OER providing flexible and diverse access to content for both teachers and students. This flexibility enables learners to explore a wide range of materials. By fostering independent learning, OER supports students in selecting resources that align with their needs and applying their knowledge to develop innovative projects through experimentation. Karunanayaka and Naidu [53] found that personalized access to OER enhances creativity and encourages exploration beyond the classroom, aligning with the model's goal of fostering innovation. Additionally, Buckley *et al*. [54] emphasized the importance of formative assessments in supporting continuous learning and improvement, particularly in STEM education. These findings highlight the value of integrating accessible learning resources and authentic assessments to enhance the learning model's effectiveness.

The eight-step instructional design model to enhance innovator competencies involves essential steps that contribute to effective learning. The first step is needs assessment, where instructors analyze learners' context and requirements to ensure the design meets actual needs, aligning with DeRosa and Robison [55] on the importance of understanding learner needs through OER. The second step involves analyzing learners and instructors to tailor activities to capabilities, identifying strengths and limitations, as highlighted by Li and Zhan [56]. The third step focuses on content, context, and learning environment analysis, enhancing learning efficiency through appropriate settings, as emphasized by Karunanayake and Naidu [53]. In the fourth step, instructors align content with learning objectives, fostering clear, goal-oriented processes, supported by research from Keinanen and Butter [57]. The fifth step designs activities using the design thinking process to develop essential skills, with Al Abri [58] emphasizing the integration of OER to support open practices. The sixth step provides realistic experiences that enhance knowledge applicability, as shown by Hammond and Albert [59], who stress the importance of experiential activities. The seventh step implements the learning plan in real settings, linking prior knowledge with new concepts, fostering real-world problem-solving through design thinking, as noted by Waity *et al*. [60]. Finally, the assessment step evaluates learning success and progress in innovator competencies, aligning with Rosen *et al*. [61], who advocate for diverse assessments of creativity, problem-solving, and teamwork.

The eight-step instructional design model demonstrates greater detail than the ADDIE model. The analysis phase is divided into multiple dimensions, including needs assessment, learner analysis, instructor analysis, and learning context analysis, enabling deeper and more comprehensive responses to the target group's needs. The design phase emphasizes integrating DT and OER to create activities that connect to real-world scenarios while promoting learner-centered education. The development phase focuses on realistic activities and practical applications, while the evaluation phase highlights assessing real-world outcomes, such as creativity and innovator competencies. In contrast, ADDIE lacks the same level of detail in these dimensions, making the eight-step model more suitable for learning that prioritizes innovation and specific results.

The statistically significant improvement in students' knowledge following the model's implementation confirms the effectiveness of the learning activities. Teachers play a pivotal role in designing learning activities and integrating OER to enhance students' knowledge and skills. By incorporating DT into the learning process, teachers foster problem-solving, innovation, and creativity, aligning activities with modern learning needs for flexibility and adaptability. OER provide students with diverse, high-quality resources, enabling independent exploration and a deeper understanding of innovative concepts, significantly improving their competencies in DT and innovation creation.

Research supports this approach, as Sandanayake [62] confirmed that blended learning using OER enhances both academic achievement and student engagement. Furthermore, students' innovation projects demonstrated high ratings in creativity, feasibility, impact, and scalability, reflecting their ability to address real-world challenges effectively.

The evaluation of students' innovation projects following the implementation of the Instructional Design Model demonstrated good results, attributed to the integration of DT into learning activities. Students were required to create tangible, real-world innovation projects by applying user-centered approaches. This involved analyzing needs, identifying focused problems, and brainstorming creative solutions, which led to the development of functional prototypes. These prototypes were tested and refined iteratively based on feedback, ensuring the innovations were both feasible and scalable. This hands-on process emphasized the importance of producing actual outcomes while fostering creativity, collaboration, and problem-solving skills. These findings align with Bustard *et al*. [63], who highlighted DT s role in enhancing engagement and producing impactful, user-oriented innovations.

The evaluation of innovator competencies at a "Good" level is attributed to the instructional design process, which focused on developing these competencies through a systematic approach that integrated DT and OER. Teachers began by analyzing learners' needs and aligning activities with their abilities, linking real-world problems to learning content to ensure relevance and practical application. The iterative learning process embedded within the model also nurtured essential innovator competencies. The five stages of DT which include, Empathy, Define, Ideate, Prototype, and Test, were applied to enhance these competencies. Students practiced critical skills such as understanding user needs, defining clear problems, brainstorming creative solutions, building prototypes, and refining innovations through testing. These stages helped develop key innovator competencies, including questioning, observation, connecting ideas, experimentation, and networking, enabling students to create innovative and impactful solutions. This aligns with findings by Aris *et al*. [64] who confirmed that DT promotes problem-solving, teamwork, and innovative thinking.

Positive feedback from students regarding their engagement and satisfaction further highlights the model's relevance in rebuilding effective learning environments disrupted by the pandemic. Gopal *et al*. [65] and Safarini and Kusumah [66] found that OER enhances self-directed learning, motivation, and engagement, reinforcing the importance of such models in the post-pandemic era.

The study found a moderate positive correlation between Innovation Projects and Innovator Competencies, indicating that stronger quality innovations contribute to higher competencies. This is because, during the process of developing innovative outputs, learners are tasked with creating projects based on problems assigned by their instructors. To solve these problems, learners must engage in collaborative work, formulate questions to gather data, observe various elements to connect ideas, and experiment with creating prototypes to test whether the solutions effectively address the problems. If students successfully develop high-quality innovations, this reflects their strong innovator competencies, which are critical for their development during the process of creating these outputs. This aligns with Kairisto-Mertanen *et al*. [67], who highlight that innovation pedagogy enhances creativity, teamwork, and problem-solving through real-world projects, enabling students to create meaningful innovations. Similarly, Bragos *et al*. [68] emphasize that experiential learning in engineering strengthens experimentation and collaboration, essential for scalable innovations. These findings stress the need to integrate such methods into curricula to prepare students for innovation-driven learning.

The research findings indicate significant positive outcomes in developing students' innovator competencies. However, implementing the model effectively requires attention to three critical aspects: teachers, learners, and the model's limitations. In terms of teachers, training is required in designing learning based on DT principles that foster innovation, as well as in utilizing OER systems and related learning tools. This will enable teachers to effectively monitor students' progress, provide guidance, and comprehensively assess learning outcomes. Learners must grasp the concepts of OER and DT, which can be facilitated through orientation sessions. Active participation in diverse activities, such as projects, teamwork, and discussions, is essential for cultivating real-world innovation skills. Despite its strengths, the model is most suitable for disciplines focused on design, problem-solving, and innovation. Applying it in other contexts may require customizing activities and content to align with specific educational environments.

VII. Conclusion

This research confirms the effectiveness of integrating OER with DT to address educational challenges in the post-COVID-19 era. The model provides a structured eight-step process for educators to design meaningful learning activities, fostering students' innovator competencies and promoting innovation projects. Its strength lies in a detailed instructional design process, encompassing needs analysis, learner analysis, content determination, and the development of learning activities, instructional materials, and assessments. This ensures that the learning activities designed by teachers enable students to produce innovative outputs and develop innovator competencies through real-world-relevant projects.

The findings demonstrate significant improvements in students' innovator competencies., validating the impact of flexible and relevant learning activities facilitated by teachers. The use of OER provided students with access to diverse resources, supporting self-directed learning and encouraging exploration beyond traditional classroom boundaries. Additionally, the integration of DT and OER empowered students to develop practical problem-solving skills by fostering adaptability and critical thinking, which are key attributes of innovators. Furthermore, the analysis showed a moderate positive correlation between students' innovator competencies and their project outcomes, indicating that stronger competencies lead to better performance. These findings highlight the need to foster these skills to enhance students' ability to create meaningful innovations.

Positive feedback from students regarding their engagement and satisfaction highlights the relevance of this model in creating effective learning environments impacted by the pandemic. By contributing to the growing body of knowledge on innovative instructional models, this research enables educators to design impactful learning activities that foster students' innovator competencies, benefiting both teachers and learners alike. Moreover, the national significance of this model lies in its ability to equip students with the skills needed to drive innovation and address complex societal challenges, aligning with the country's priorities to enhance global competitiveness and promote lifelong learning in the post-pandemic era. Future research could further refine the model for diverse educational contexts and evaluate its long-term impact on learners' innovation capabilities, ensuring its scalability and effectiveness in fostering meaningful educational transformation.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

SL designed the research and conducted the study by creating the Instructional Design Model and Open Educational Resources (OER), collecting the data, and writing the manuscript; EB contributed by designing the activities for the model, developing the research instruments, analyzing the data, and interpreting the results; all authors have approved the final version of the manuscript.

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References

[1] K. J. H. L. Koh, C. S. Chai, B. Wong, and H.-Y. Hong, "Design thinking and 21st century skills," *Design Thinking for Education: Conceptions and Applications in Teaching and Learning*, pp. 33–46. Springer, 2015.

[2] S. Gronman and E. Lindfors, "The process models of design thinking: A literature review and consideration from the perspective of craft, design and technology education," *Techne Serien—Forskningi Slöjdpedagogik Och Slöjdvetenskap*, vol. 28, no. 2, article 2, 2021.

[3] A. Gasparini, "Perspective and use of empathy in design thinking," in *Proc. International Conference on Advances in Computer-Human Interactions*, pp. 49–54, 2015.

[4] S. Boonlert and T. Suthathip, "Impacts of pandemic on education sector in Thailand," *PMC*, vol. 12, no. 1, article 110, 2022.

[5] J. E. Maldonado and K. De Witte, "The impact of school closures on student learning during the COVID-19 pandemic," *Educational Researcher*, vol. 51, no. 7, pp. 606–617, 2022.

[6] J. Schult, N. Mahler, B. Fauth, and M. A. Lindner, "Did students learn less during the COVID-19 pandemic? Reading and mathematics competencies before and after the first pandemic wave," *OSF Preprints*, Mar 11, 2021.

[7] G. Manikutty, S. Sasidharan, and B. Rao, "Driving innovation through project-based learning: A pre-university STEAM for Social Good initiative," *arXiv preprint*, arXiv:2211.01998, 2022

[8] C. N. Akpen, S. Asaolu, S. Atobatele, H. Okagbue, and S. Sampson, "Impact of online learning on student's performance and engagement: A systematic review," *Discover Education*, vol. 3, article 205, 2024.

[9] D. T. K. Ng, J. K. L. Leung, J. Su, R. C. W. Ng, and S. K. W. Chu, "Teachers' AI digital competencies and twenty-first century skills in the post-pandemic world," *Educational Technology Research and Development*, vol. 71, pp. 137–161, 2023.

[10] R. Donnelly and H. A. Patrinos, "Learning loss during COVID-19: An early systematic review," *Prospects*, vol. 51, no. 4, pp. 601–609, 2022.

[11] UNESCO, "Open educational resources: The way forward," UNESCO Report, 2008.

[12] E. Hennessey and J. Mueller, "Teaching and learning design thinking: How do educators see DT fitting into the classroom?" *Canadian Journal of Education/Revue Canadienne de l'éducation*, vol. 43, no. 2, pp. 498–521, 2020.

[13] A. G. Spatioti, I. Kazanidis, and J. Pange, "A comparative study of the ADDIE instructional design model in distance education," *Information*, vol. 13, no. 9, article 402, 2022.

[14] V. S. Gerlach and D. P. Ely, *Teaching and Media: A Systematic Approach*, Englewood Cliffs, NJ: Prentice-Hall, 1980.

[15] O. Natakuatoong, *Designing Instructional Systems: Summary of the Course on Systems Approach in Education*, Bangkok: Sukhothai Thammathirat Open University Press, 2020.

[16] G. R. Morrison, S. M. Ross, and J. E. Kemp, *Designing Effective Instruction (3rd ed.),* New York: John Wiley and Sons, Inc., 2001.

[17] S. E. Smaldino, D. L. Lowther, C. Mims, and J. D. Russell, *Instructional Technology and Media for Learning (12th ed.),* Boston: Pearson Education, Inc., 2018.

[18] V. V. Senadheera, D. S. Ediriweera, and T. P. Rupasinghe, "Instructional design models for digital learning in higher education: A scoping review," *Journal of Learning for Development*, vol. 11, no. 1, pp. 15–26, 2024.

[19] T. Khammani, *Learning Design*, Bangkok, Thailand: Chulalongkorn University Press, 2017.

[20] UNESCO. (2019.) Recommendation on Open Educational Resources (OER). *United Nations Educational*, *Scientific and Cultural Organization*, [Online]. Available: https://unesdoc.unesco.org/ark:/48223/pf0000370937

[21] D. Wiley, "The open future: Openness as catalyst for an educational reformation," *EDUCAUSE Review*, vol. 49, no. 4, pp. 29–36, 2014.

[22] D. L. Cozart, E. M. Horan, and G. Frome, "Rethinking the traditional textbook: A case for open educational resources (OER) and no-cost learning materials," *Teaching & Learning Inquiry*, vol. 9, no. 2, 2021.

[23] A. Tlili, J. Garzon, S. Salha, R. Huang, L. Xu, D. Burgos, M. Danden, O. Farrell, R. Farrow, A. Bozkurt, T. Amiel, R. McGreal, Lopez-Serrano, and D. Wiley, "Are open educational resources (OER) and practices (OEP) effective in improving learning achievement?" *International Journal of Educational Technology in Higher Education*, vol. 20, article 54, 2023.

[24] L. Fischer, J. Hilton III, V. Clinton-Lisell, Y. Xiong and D. Wiley, "The interaction of Open Educational Resources (OER) use and course difficulty on student course grades in a community course difficulty on student course grades in a community college" *Education, Health & Behavior Studies Faculty Publications,* vol. 4, no.1, 2021.

[25] D. Otto, "Adoption and diffusion of open educational resources (OER) in education," *International Review of Research in Open and Distributed Learning*, vol. 20, no. 5, pp. 122–140, 2019.

[26] T. Brown, "Design thinking," *Harvard Business Review*, pp. 1–10, 2008.

[27] N. Cross, *Design Thinking: Understanding How Designers Think and Work*, Berg, 2011.

[28] M. Carroll, S. Goldman, L. Britos, J. Koh, A. Royalty, and M. Hornstein, "Destination, imagination and the fires within: Design thinking in a middle school classroom," *International Journal of Art and Design Education*, vol. 29, no. 1, pp. 37–53, 2010.

[29] J. H. L. Koh, C. S. Chai, B. Wong, and H. Y. Hong, "Design thinking for education: Conceptions and applications in teaching and learning," *The Asia-Pacific Education Researcher*, vol. 24, no. 3, pp. 495–503, 2015.

[30] N. Wannapiroon, S. Shawarangkoon, C. Chawarangkoon, A. Kucharoenthavorn, and P. Wannapiroon, "Metaverse Learning Experience Platform (MLXP) for immersive design thinking to enhance digital intelligence quotient and virtual game developer skills,"

International Journal of Information and Education Technology, vol. 13, no. 12, pp. 1879–1889, 2023.
[31] H.-K. Lee and J. E. Park, "Digital responsibility insights from a cross-cultural design thinking workshop for creativity," *Creativity Studies*, vol. 15, no. 2, 2022.
[32] J. Liedtka and S. Kaplan, "How design thinking opens new frontiers for strategy development," *Strategy & Leadership*, vol. 47, no. 2, pp. 3–10, 2019.
[33] G. Ilipinar, W. J. Johnston, J. Montana, J.-C. Spender, and D. P. Truex, "Design Thinking in the Postmodern Organization," *SSRN Electronic Journal*, vol. 10, no. 11, pp. 1203–1212, 2011.
[34] M. Canina and C. Bruno, "Design thinking via flipped classroom," in *Proc. the 20th International Conference on Engineering and Product Design Education*, pp. 468–475, 2018.
[35] J. Dyer, H. Gregersen, and C. M. Christensen, *The Innovator's DNA: Mastering the Five Skills of Disruptive Innovators*, Harvard Business Review Press, 2011.
[36] M. Fullan and M. Langworthy, *A Rich Seam: How New Pedagogies Find Deep Learning*, Pearson, 2014.
[37] J. D. Donovan, A. Maritz and A. McLellan "Innovation training in the Australian advanced manufacturing industry," *Journal of Vocational Education and Training*, vol. 65, no. 2, pp. 256–276, 2013.
[38] S. Chaemchoy, "Factor analysis of Thai students' innovator and entrepreneur competency," *Kasetsart Journal of Social Sciences,* vol. 44, no. 3, pp. 939–946, 2023.
[39] M. A. Schilling, *Strategic Management of Technological Innovation*, 5th ed., McGraw-Hill Education, 2017
[40] M. B. Manuel, M. G. Monica, and M. G. Juan, "Exploring skills and competencies of innovation: a measurement model," in *Proceedings of EDULEARN17 Conference*., 2017, pp. 10161–10165.
[41] N. Kiattikan, T. Uppamaiathichai, and N. Prechanban, "The elements of innovative thinking skills for school administrators," *Journal of Roi Kaensarn Academi*, vol. 7, no. 3, pp. 60–69, 2022.
[42] W. D. Schindel, S. N. Peffers, J. H. Hanson, J. Ahmed, and W. A. Kline, "All innovation is innovation of systems: An integrated 3-D model of innovation competencies," in *Proc. the 2011 ASEE Annual Conference and Exposition*, American Society for Engineering Education, 2011.
[43] S. Buck, "2012 presidential address: Daring to be different using five discovery skills," *Journal of Family and Consumer Sciences*, vol. 104, no. 3, pp. 8–11, 2012
[44] R. Butter and W. van Beest. Psychometric validation of a tool for innovation competencies development and assessment. [Online]. Available: www.fincoda.eu/fincoda-blog/2017/3/27/psychometric-validation-of-a-tool-for-innovation-competencies-development
[45] N. Phumeechanya and S. Soonthara, "The development of engineering design process on web application learning model to enhance web programming skills for computer education students," *International Journal of Information and Education Technology*, vol. 13, no. 10, pp. 942–953, 2023.
[46] D. Beijaard, P. C. Meijer, and N. Verloop, "Reconsidering research on teachers' professional identity," *Teaching and Teacher Education*, vol. 20, no. 2, pp. 107–128, 2004.
[47] A. Datnow and V. Park, *Professional Collaboration with Purpose: Teacher Learning towards Equitable and Excellent Schools*, Routledge, 2018.
[48] M. Bond, S. Bedenlier, V. I. Marin and O. Zawacki-Richter. (2021). Student engagement in open, distance, and digital education. *SpringerLink*. [Online]. Available: https://link.springer.com/article/10.1007/s11423-016-9434-9
[49] J. Li, "Learner-centred learning tasks in higher education: A study on perception among students," *Educ. Sci*., vol. 11, no. 230, 2021.
[50] B. Saçak, A. Bozkurt, and E. Wagner, "Learning design versus instructional design: A bibliometric study through data visualization approaches," *Education Sciences*, vol. 12, no. 11, p. 752, 2022.
[51] C. Novo, M. Tramonti, A. M. Dochshanov, D. Tuparova, B. Garkova, F. Eroglan, T. Uğraş, B. Yücel-Toy, and C. V. Carvalho, "Design thinking in secondary education: Required teacher skills," *Education Sciences*, vol. 13, no. 10, Article 969, 2023.
[52] R. Halverson, K. J. Spring, S. Huyett, J. Henrickson, and R. Shapiro, "Blended learning for personalized learning: An emerging technology landscape," *Journal of Teaching and Learning*, vol. 10, no. 1, pp. 20–35, 2014. doi: https://doi.org/10.1007/s10798-018-9444-5
[53] S. P. Karunanayake and S. Naidu, "Impact of integrating OER in teacher education at the Open University of Sri Lanka," in C. Hodgkinson-Williams and P. B. Arinto, Eds., *Adoption and Impact of OER in the Global South*, pp. 459–498, 2017.
[54] J. Buckley, E. Hartell, and N. Blom, "Current perspectives on the value, teaching, learning, and assessment of design in STEM education," *Frontiers in Education*, vol. 8, 2023.
[55] R. DeRosa and S. Robison, *From OER to Open Pedagogy: Harnessing the Power of Open*, Open. London: Ubiquity Press, 2017.
[56] T. Li and Z. Zhan, "A systematic review on design thinking integrated learning in K-12 education," *Applied Sciences,* vol. 12, no. 16, pp. 1–34, 2022.
[57] M. Keinanen and R. Butter, "Researching learning environments and students' innovation competences," *Education and Training*, vol. 61, no. 6, pp. 715–727, 2019.
[58] M. A. Abri, "Exploring the pedagogical impact of integrating open educational resources in a college course: A design-based research study," Master's thesis, George Mason University, 2020.
[59] A. Hammond and C. D. Albert, "Learning by experiencing: Improving student learning through a Model United Nations simulation," *Journal of Political Science Education,* vol. 16, no. 4, pp. 441–458, 2020.
[60] J. Waity, A. Sellon, and B. Williams, "Using design thinking to solve real-world problems: A pedagogical approach to encourage student growth," *Journal of Effective Teaching in Higher Education*, vol. 6, no. 2, 2023.
[61] Y. Rosen, K. Stoeffler, and V. Simmering, "Imagine: Design for creative thinking, learning, and assessment in schools," *Journal of Intelligence*, vol. 8, no. 2, p. 16, 2020.
[62] T. C. Sandanayake, "Promoting open educational resources-based blended learning," *International Journal of Educational Technology in Higher Education*, vol. 16, no. 1, 2019.
[63] J. Bustard, K. Miller, and P. Joseph-Richard, "Finding your north star in active learning environments: A framework to support experience co-creation with students and stakeholders," in *Proc. the Irish Academy of Management Conference 2021*, 2021.
[64] N. M. Aris, N. H. Ibrahim, and N. D. A. Halim, "Design and development research (DDR) approach in designing design thinking chemistry module to empower students' innovator competencies," *Journal of Advanced Research in Applied Sciences and Engineering Technology*, vol. 44, no. 1, pp. 55–68, 2024.
[65] R. Gopal, V. Singh, and A. Aggarwal, "Impact of online classes on the satisfaction and performance of students during the pandemic period of COVID-19," *Education and Information Technologies*, vol. 26, no. 6, pp. 6923–6947, 2021.
[66] D. Safarini and Y. S. Kusumah, "Students' satisfaction and performance in the Open Educational Resources (OER): Integrated online calculus course," *International Journal of Technology in Education and Science*, 2022.
[67] L. Kairisto-Mertanen, T. Penttila and J. Nuotio, "Innovation pedagogy: Learning through active multidisciplinary methods," *European Journal of Education*, vol. 47, no. 1, pp. 77–89, 2012.
[68] R. Bragos, E. Sayrol and R. Vidal, "Developing innovation competences in engineering students: A comparison of two approaches," *European Journal of Engineering Education*, vol. 35, no. 2, pp. 131–147, 2010.