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ENHANCING SCIENCE TEACHERS' 4CS SKILLS COMPETENCIES: A DESIGN THINKING BASED PROFESSIONAL DEVELOPMENT INTERVENTION IN ELEMENTARY EDUCATION

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Abstract: The purpose of this study was to understand the development of the 4Cs skills and the impressions of science teachers who involved in a training intervention based on the design thinking. To explore the study objectives, a quasi-experimental approach was employed on a 25 teachers who teach science in elementary schools. The assessment of teachers' 4 Cs skills is conducted using a cognitive test of critical and creative thinking skills. The test have been validated and reliable in terms of their psychometric properties. (T) test results indicate the significant difference between the mean of the pre and post test to the post test. A survey was used to measure the soft skills, which are communication and collaboration skills. The result of the study indicates the effectiveness of the Design Thinking Approach in developing 4 Cs skills among teachers. Based on the rsults four of recommendations were listed.
Keywords: Design thinking; Critical thinking; Creative thinking; Communication skills; Collaborative skills**.**

INTRODUCTION:

Teachers have recently become central to educational development, bearing much of the responsibility for either the success or failure of the education system. To do so, they face multiple challenges, including understanding the diverse needs and characteristics of students, implementing new pedagogical practices that meet students' academic, social, and emotional needs (Li & Zhan, 2022). This requires more attention to serve teachers before and during services to become more professional to overcome these challenges. Empirical research such as Noel and Liu (2016), Tu et al (2018), Yeping et al (2019), Regina et al (2020), Stith et al (202), Haryani et al (2021), Veerasinghan et al (2021), Prayogi et al (2023), Al-Amry and Al-Abd Al-Kareem (2024) show that Design Thinking (DT) impacts multiple domains of learning, including: design performance, emotional and social development, subject learning outcomes and skills. As an innovative problem-solving method, design thinking has expanded beyond its professional roots to become a general paradigm for addressing complex challenges.

Design thinking competencies have been categorized into five-stage process: empathy, define, ideate, prototype, and test (Regina et al, 2020; Stith et al, 2020; Cook & Bush, 2018; Noel & Liu, 2016). Li and Zhan (2022) describe design thinking as "a way of identifying human needs and creating new solutions using the tools and mindsets of design practitioners" (P. 78). The theoretical foundation of DT is linked to Dewey's concepts of pragmatist inquiry and aesthetic experience, with training goals that emphasize solving complex, open-ended problems and developing communication, cooperation, creativity, and critical thinking (Regina et al, 2020).

Moreover, design thinking has been adopted by both education and industry as an iterative, human-centered design approach, popularized by the Hasso Plattner Institute at Stanford University (Regina et al, 2020; Stith et al, 2020; Hasso Plattner Institute, 2022). Design thinking aligns with the shift from project-based to experiential learning aimed at developing global competencies. Integrating design thinking, students connect multidisciplinary knowledge and skills while engaging in pedagogical approaches that involve problem-based learning, project-based learning, or inquiry-based classroom activities (Rex et al, 2017; Li et al, 2019; Stith et al, 2020; Ladachart et al, 2022). By defining the problem, imagining solutions, and testing them, designers can ensure they meet the users' needs rather than addressing another extraneous purpose.

This approach can be an important tool for teachers to create new teaching methods in a classroom since the teachers who teach science subjects are facing challenges in designing lessons that can be engaging and create interest in science among students (Li et al, 2019; Li & Zhan, 2022). Design thinking is relevant to learning theories within education, developmental psychology, and social psychology. Vygotsky's (1976) social learning theory states that interacting with others is essential to learning, and experiential learning theory (Eden & Julie, 2020). Hasso Plattner Institute (2022) describes learning as the process through which knowledge results from gaining experience. Indeed, Design thinking prepares students for future life and careers by cultivating skills such as responsible, active, social, creative, and critical thinker (Snape, 2017; Walser, 2018; Badr, 2021).

Design thinking is recognized as a valuable approach for enhancing the skills of 21st-century students, preparing them with the necessary tools to tackle the ever-changing challenges of our global society in the future (Prayogi et al, 2023; Wright & Wrigley, 2019). Educators and scholars increasingly emphasize the importance of 21st-century skills, especially 4Cs: critical thinking, creative thinking, collaborative, and communication (Margarida,

2015; Badr, 2021; Haryani et al, 2021). To succeed in a globalized, digital society, students need to begin practicing these skills early in their education. Teachers play the role of coaches, enabling active learning while encouraging students to collaborate with peers and stakeholders to generate creative solutions. Eden and Julie (2020) state that one potential challenge associated with implementing Design thinking in an educational context is assessment. Given that Design thinking shares some crossover with general creativity (e.g., generating solutions, reiterating), it is not surprising that many Design thinking assessments are based on tests of creativity.
With the advent of globalization, digitization, and the fourth industrial revolution, increased reliance on scientific innovation and patents has taken a major role as a determinant of national development. Science education is widely recognized as a key to develop economic growth internationally with reports indicating the need for a trained scientifically literate workforce, stating that gifted students address complex global challenges using scientific methods (Tu et al., 2018; Ahmad et al., 2024). Science education, ideally, should yield not only academic and economic outcomes, but also personal, social, and economic development. It is recognized widely that science learning and research should develop personal attributes, such as 21st-century skills, soft skills, or general capabilities such as problem-solving, collaboration, creativity, and innovation (Tu et al., 2018; Al-Amry & Al-Abd Al-Kareem, 2024). These are often considered skills that may be associated with pedagogy of inquiry-based learning. Learning about science in practical scientific terms is a social obligation, and it is critical in solving real-world problems. To remain competitive globally, future national productivity will include preparing individuals for science careers. The youth in many nations need to be sufficiently educated in scientific literacy to deal with such complex world problems confidently (Haryani et al., 2021; Ahmad et al., 2024). It is well-known that science lies at the root of innovation and patent formulation; similarly, Veerasinghan et al. (2021) point to scientific literacy as an indicator of future readiness. Thus, a key challenge for science education in modern times is creating a learners' capacity to get by in the ever-uncertain and changing world of future careers and societies.
Despite growing attention, research on design thinking in education remains uneven. DT has gained popularity in K–12 education over the past decade, most studies have focused on middle school students, often in small groups and short-term projects, with particular attention to arts subjects (Li et al, 2019; Ahmad et al ,2024). Li and Zhan (2022) claim that less studies are known about how DT applies on neither science or teachers during services. Systematic reviews of research suggest the need for more evidence on DT's effectiveness on teachers, particularly during services (Li & Zhan, 2022; Prayogi et al, 2023). More empirical evidence is required to determine whether DT is an effective approach for science teachers and how it influences their way of teaching.
Ultimately, this research argues that beyond advancing design thinking principles in education, DT fosters essential skills including communication, collaboration, teamwork, creativity, critical thinking, and professionalism. Moreover, as DT becomes more widely applied, it is equally important to assess its impact on educators' practices and experiences.

Research problem

Reviewing research shows that teachers do not understand the application of some of the 21st-century skill (UNESCO-UNEVOC, 2022). Thus, their students are weak in using critical and creative thinking in solving problems in science classes. Nowadays, a big problem in education of science is the lack of use of higher order thinking skills in a classroom. There is also an absence of emphasis on learning experiences that provide real student-centered, challenging problems and opportunities for collaboration or opportunities for students to apply creativity in coming up with solutions to real world problems
Additionally, the biggest challenge for science teachers in elementary schools is that few guidelines or models exist regarding using 4Cs skills (called soft skills) in teaching science (Ahmad et al, 2024). Therefore, this research recognized the gains that can be made from utilizing design thinking in education, especially in the global quest of teaching 21st-century skills. Specifically, 4Cs skills, which are critical thinking, creative thinking, collaborative, and communication. This research has recommended using design thinking in the Lesson plan and train teachers to prepare activities to meet 4Cs skills. The research's purpose is to facilitate science teachers by integrating design thinking opportunities into classrooms and training teachers to use the 4Cs skills in their classroom activities.

Research questions are:

1. Are there statistical differences in participating science teachers on a training program based on design thinking to develop their 4Cs cognitive skills (critical thinking, creative thinking)?
2. To what extent do science teachers participating on a training program based on design thinking develop the 4Cs soft skills (collaborative, and communication).

Research Objectives

The purpose of this study was to understand the development of the 4Cs skills and the impressions of science teachers who involved in a training program based on the design thinking.

Research Significance

1. Design thinking revolves around human needs and is based on the principle of participatory work and encourages creativity. This is consistent with the modern trend in developing 21st-century skills.
2. This research contributes to clarifying how to invest in design thinking and use it to develop 4Cs skills in science classrooms.

3. Officials at the Ministry of Education reported that the development of programs and activities based on design thinking in the field of professional development for teachers is as a modern trend.
4. This research provides teachers with theoretical and practical knowledge about investing in design thinking in their educational practices to enhance 4Cs skills for student performance.

Delimitation of the Research

Current research focuses on studying the impact of design thinking professional program on the development of 4Cs skills (critical thinking, creative thinking, collaborative, and communication) of science teachers. The topic of water, air, and earth pollutions were chosen and modified according to the five stages of design thinking model. The study sample consisted of 25 teachers who teach science in elementary schools at Majmaah schools, during the first semester of the academic year 1446 / 2025.

List of Terms

Design thinking model

Stith et al (2020) state that "design thinking is a systemic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specific set of constraints" (p. 104). In this study design thinking model is as the teaching material to explore the key points for successful teaching, and the research focus was on design thinking five-stage process: empathy, define, ideate, prototype, and test.

21st-century skills

The most recent definition of 21st-century skills is by UNESCO-UNEVOC (2022), which states that "twenty-first-century skills are abilities and attributes that can be taught or learned in order to enhance ways of thinking, learning, working and living in the world. These include creativity and innovation, critical thinking and problem solving, communication, collaboration, information literacy, ICT literacy, citizenship, life and career skills, and personal and social responsibility."(p.17)

4 Cs skills (critical thinking, creative thinking, collaborative, and communication).

This study adapted the definition of Badr (2021) which states that communication, collaboration, critical thinking, and creative thinking formulate the four Cs skills that he believes to be necessary for students to master in the 21st-century. These skills are considered as key competencies essential for success in the 21st-century workplace and education.

LITERATURE REVIEW

Design Thinking for 21st-century Learning

Design Thinking has been used across, and applied across various domains such as business, innovation and social impact, education and learning in recent years. Prayogi et al. (2023) identify Design Thinking as a powerful and widespread approach for driving educational innovation. Through the many ways it is being researched—or its application to real-world teaching practices, its ideas attract and inspire research on integrating Design Thinking and applying it in many contexts outside the traditional purview of design professionals (Panke, 2019; Li & Zhan, 2022; Prayogi et al., 2023).

In contrast to traditional teaching methods, design thinking is both a mindset and a dynamic, non-linear process (Rex et al., 2017; Regina et al., 2020; Veerasinghan, 2021). This approach comes in handy in education as it gives the student a perspective to inspire change through designer-like thinking. Design thinking has a specific approach focused on the process that is quite different from most other techniques. As a creative lens, it adopts a human-centered, action-oriented, prototype-driven and non-judgmental mindset (Rex et al., 2017; Panke, 2019; Regina et al., 2020; Veerasinghan, 2021; Li & Zhan, 2022; Prayogi et al., 2023). This orientation generates positivity, removes fears of failure, enables participants to work together and share their thoughts along the whole journey.

Design thinking is a model that uses the designer's sensibility and methods to satisfy the students'needs to arrive at a strategy that is academically feasible. In addition, Rex et al (2017) explain that design thinking is a model to build infusing insight into the process in order to address unimaginable issues and problems. These issues and problems are what is referred by most design thinkers as "wicked problems" or problems that seems to have no solutions or whose solutions can only be solved by multidisciplinary means (Panke, 2019; Prayogi et al, 2023). In short, Rex et al (2017) state that design thinking uses the mindsets and methodologies often used by designers to create new ideas and solutions, that satisfy the desires of the students' needs. When fulfilling one's mind of traditional solutions it will lead to new and creative problem solving. Rex et al (2017) further explain that as a strategy employing abductive reasoning, design thinking is interpretive, experimental, and opportunistic that in sum builds creative confidence.

Teachers who have used design thinking in their classrooms claim that it encourages critical thinking, problem-solving, creativity, and collaboration (Noel & Liu, 2016; Rex et al., 2017; Panke, 2019; Regina et al., 2020; Veerasinghan, 2021). Additionally, Eden and Julie (2020) characterize design thinking as a constructivist learning approach that motivates students to explore, innovate, and solve problems. Rex et al. (2017) highlight the successful functioning of design thinking in support of 21st-century learning by the application of design thinking on complex projects and its holistic constructivist features. Design thinking is an all-round approach to design cognition which enables students to be successful in

interdisciplinary activities and at the same time, creatively responds to difficult problems of real-world application.

Design thinking can significantly enhance creativity and innovation, particularly when applied in collaborative, multidisciplinary problem-solving contexts (Rex et al., 2017; Regina et al., 2020; Veerasinghan et al., 2021; Ladachart et al., 2022). According to Noel and Liu (2016) from Carroll (2010), study on design thinking in middle school classrooms, demonstrated that it leads to increased student engagement in learning by fostering creativity and collaboration. Students become more willing to listen, take risks, and share ideas with their peers, thereby enriching the learning process.

Design Thinking Application in Teaching & Learning

As IDEO (2022) reported, universities including Rotman and Stanford pioneered early successful DT integration models for primary and secondary schools, following the international experience of design firms. Those initiatives included building an interdisciplinary design curriculum guided by professors of a university in a public charter school, designed ultimately to stimulate creativity through teamwork. Students were also to do with a high degree of empathic work solving complex problems among them, where no one solution is available (Noel & Liu, 2016; Rex et al., 2017; Regina et al., 2020; Veerasinghan et al., 2021; Ladachart et al., 2022). Because of this, Prayogi et al. (2023) argue in their paper on teaching strategy that DT is rooted in Vygotsky's sociocultural constructivist learning theory, using scaffolding and encouraging a learning style that is constructive with motivation for exploration, new ideas, imagination, and other metacognitive skills among others.

Design thinking is an innovative educational approach that transforms learning by applying a constructivist, human-centered methodology to teaching and curriculum development. Eden and Julie (2020) claim that progressive universities like Stanford have initiated design thinking applications in education. The approach is fundamentally rooted in constructivist learning theory, emphasizing collaborative problem-solving and skill development. Key evidence supports that design thinking's effectiveness: Rex et al (2017) note that it advances creativity and innovation through an empathetic and flexible approach and increases students' motivation and develops reflection skills across multiple design levels. The methodology goes beyond traditional teaching by challenging students to solve complex problem through interdisciplinary, collaborative activities that foster critical and creative thinking (Eden & Julie, 2020).

As a designer, thinking requires a range of cognitive abilities and knowledge. Designers approach complex problems routinely, and create multiple solutions, analyze them, and refine them (Hasso Plattner Institute, 2022). In the same way, students should be invited to solve real-world problems, and work with problems to analyze and evaluate them to develop creative solutions. Design Thinking (DT) utilizes constructivist approaches of experiential learning and complex problem-solving across all age groups. DT offers core attributes as a constructivist teaching and learning method, such as motivation for exploration and creative thinking (Prayogi et al., 2023). Within the framework of DT, these tendencies contribute to the development of 21st-century skills. With strong teacher-student relationships, students have been inspired to explore, build confidence, and collaborate to express ideas and share knowledge. DT processes point educators in the direction of constructivist teaching practices and can be implemented through short, integrated sessions in science classes.

While there is growing interest regarding the application of Design Thinking (DT) in schools, there is still a lack of studies critically reviewing recent research and reflecting actual teaching practices (Panke, 2019; Veerasinghan et al., 2021; Hasso Plattner Institute, 2022). Growing interest in DT has fuelled international research on the subject. What problems are implicated in this trend as to the use of DT as a teaching-learning methodology? How has DT been used as a tool for curriculum development in schools? (Rex et al., 2017). The aim of this study is to investigate the development of 4Cs skills (critical thinking, creativity, collaboration, and communication) and investigate the perceptions of science teachers participating in a DT-oriented training programme.

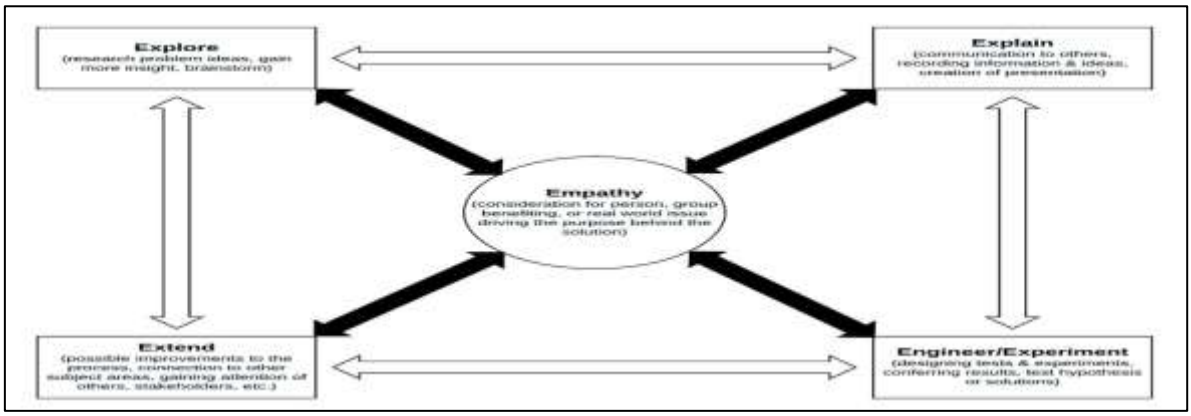

Figure 1 Five interconnecting stages of the PBDT Framework. (Regina et al, 2020)

Design thinking five stages

Figure 1 summarized the guidelines of the design thinking. Design Thinking processes foster several skills in different stages, in which expansion and integration take turns. The stages are the following as stated by Badr (2021) and Hasso Plattner Institute (2022):

Understand and Observe (Empathy)

The first step in the design process is to build up empathy and understanding of the people and the situation the problem or challenge is set in. Tu et al (2018) named this step empathize. In this step, students observe and interview deeply with users, and get to know user demands. Recording procedure, analyzes interviews with sticky notes, observes the contents to gain insight. In this stage, students access their prior knowledge and experiences.

Synthesis (Define)

In order to solve a problem and generate meaningful ideas, one has to define the problem and its context. Tu et al (2018) claims that through defining stage students can create groups like users to assist in the analysis of the lifestyle; students can use core sentences again to define the deeper demands of the role and make them consistent with the requirements for the core sentences. In this stage, students develop experiences to explore science ideas, questions, and phenomena firsthand through investigation and experimentation

Ideate (Expand)

Ideation means opening up the mind, being imaginative and generating lots of ideas for solving problems. Tu et al (2018) through this stage students develop experiences and explore science ideas, questions, and phenomena firsthand through investigation and experimentation

Prototype (Consolidating)

The prototype phase is all about experimentation to bring ideas alive, to make them tangible, actionable, and testable. Learning more about the ideas, its possibilities in form and function through building them. The goal of this stage is to challenge students to elaborate on what they have learned through new contexts and activities. Tu et al (2018) claim that students put creativity into action with a quick prototype and improve it to solve the users' problems.

Test (Expanding)

Testing means bringing the idea, the solution generated through the design process into action in order to get feedback on which to build on. Feedback from other persons, from experts, from novices, from users, everyone involved in the problem context. Tu et al (2018) claim that users test the prototype, and the model is improved according to the reality to make perfect products. In this stage, students evaluate their understanding of the science concepts through each of the previous phases.

4 Cs skills (communication, collaboration, critical thinking, and creative thinking)

The satisfaction in life depends on creative problem solving, educators in education state that art and design education can help in improving students' skills in problem solving through the design process (Noel & Liu 2016). Design Thinking challenges students to find solutions to complex problems and supports students academic performance in science subjects by contributing to critical thinking, social development, and teamwork skills (Noel & Liu, 2016; Rex et al, 2017; Regina et al, 2020; Veerasinghan et al, 2021; Ladachart et al, 2022).

Erdoğan (2019) noted that the evolving demands of the 21st-century have introduced additional skills that learners must acquire to meet contemporary expectations. Morgan (2015) explained that the Partnership for 21st-century Learning developed a framework outlining the competencies students need to succeed academically and professionally. As summarized by Geisinger (2016), this framework organizes these competencies into four main categories:

1. Content and knowledge skills, which include traditional subject knowledge as well as global awareness;
2. Learning and innovation skills, such as creativity, critical thinking, problem solving, communication, and collaboration;
3. Information, media, and technology skills, encompassing information literacy and media and technology literacy; and
4. Life and career skills, which involve intrapersonal abilities like flexibility, adaptability, initiative, self-direction, productivity, accountability, leadership, and responsibility.

Badr (2021) described the 4Cs as key 21st-century learning and innovation skills, critical thinking, creativity, communication, and collaboration. These competencies are vital for preparing students for life and future careers beyond school. Rather than being the responsibility of a single subject, they should be woven into all areas of the curriculum. In support of this view, Noel and Liu (2016) also maintained that integrating the 4Cs across different subjects is essential for equipping learners to thrive in today's world.

Similarly, Cohen (2019) viewed the 4Cs as fundamental components of the learning process that all students need in the twenty-first century. These competencies are crucial across all educational levels. Badr (2021) further argued that the 4Cs should be integrated into every subject rather than taught as standalone courses. According to both scholars, the skills themselves are not new; however, their significance has increased due to modern demands that require individuals to locate and evaluate information, make sound decisions, and generate innovative ideas.

Erdoğan (2019) emphasized that recent studies in TEFL highlight the need for English learners to develop not only strong language proficiency but also critical and creative thinking skills. Similarly, Noel and Liu (2016) argued that EFL instruction should go beyond the four basic language skills by teaching students to interpret complex viewpoints, make informed decisions, and collaborate innovatively with others. These core skills are

more effectively acquired when learners explore an EFL-related topic, engage in discussion or debate with peers, and express their ideas in writing. Additional activities—such as producing short films, performing plays, or solving problems, further strengthen students' communication, creativity, critical thinking, and teamwork abilities.'

METHODOLGY

Research Design

This investigation used a quasi experimental design. Through this study a quantitative data was collected from participants. They were teachers, who received a voluntary professional development training on DT for two weeks during the first semester of 2025 throughout the 2024-2025 academic school year. Teachers were submitted DT cognitive skills test and the survey data. Teachers were chosen for the following reasons: a) within elementary schools, teachers often act as a collective group, b) teachers' attitudes and perceptions already influence each other in the natural school environment, and c) the existing comfort and relationships during the professional program allow for a more natural communication and teamwork among participants.

Population and Sample

The population of this study is all teachers who taught science in elementary schools. The sample study is 25 female teachers who participated in the training program. Over 50% of all participants had 15 or more years of teaching experience. They have received, or are in the process of receiving, professional teaching licenses in a nationally accredited teaching licensure program. They had been chosen based on their high experience in design thinking approach. The sample was selected intentionally due to the researcher's direct teaching of the course, which facilitated the application of the teaching model.

Data Collection and Analysis

The researcher prepared two instruments:

1. The 4Cs Cognitive Skills Test

This test was designed to measure teachers' cognitive skills that are essential in the 21 st-century, such as critical thinking and creativity.

2. The 4Cs Soft skills survey

This survey was used to measure the application of 21 st-century skills. It includes indicators related to communication, collaboration.

First instrument: The 4Cs Cognitive Skills Test

The researcher developed a cognitive test to measure the teachers' development after engaging in a training program based on design thinking. The test vocabulary was formulated while considering the following: Literary and scientific studies that dealt with design thinking, prepare the list of the 4Cs skills (critical thinking, creative thinking).

The following table (1) summarizes the questions number of each critical and creative skills:

Table 1 Critical and creative skills questions number

Main skills	Sub skills	Number of questions on each skill	Questions number	Grade on each question
Critical thinking	The ability to analyze information objectively.	4	4- 11-12-17	1
	Evaluating arguments and identifying logical fallacies	4	3- 10-21-22	2
	Drawing conclusions based on evidence.	3	5- 8-9	3
	Justifying decisions with clear rationale.	4	14- 15-27-28	2
Creative thinking	Generating original ideas.	4	6- 7-23-25	2
	Flexibility in thinking and openness to new approaches.	3	1-16-19	1
	Fluency in producing multiple solutions.	4	2-13-20-24	3
	adapting ideas to different contexts.	4	18-26-29-30	2
Total		30		60

The test validity and reliability

The test content validity was tested by the following steps: review previous research and studies in the field of design thinking skills, prepare a list of design thinking skills, and review the list in its initial form to a group of experts in curriculum and teaching methods and science education. The specialists evaluate the test in terms of

content appropriateness, clarification of each item and suitability of the test to the unit of water, air, and earth pollutions. Some modifications were made based on the opinions and suggestions of the experts. Thus, the list was put in its initial form. Then, the achievement test was built based on the list of design thinking skills. The main dimension of the design thinking skills were represented in the following: Empathy, Define, Idea Generation, Modeling and Testing. The test consists of multiple-choice questions and open-ended items.

Reliability was confirmed using Cronbach's Alpha, the value was (0.88) indicating high internal consistency. Thus, the test is consistence and reliable as measurement tool.

The pilot study was used with 7 teachers prior to the actual training program. Those teachers were not participated on the study. The purpose of the piloting was to measure the validity and reliability of the test, the clarification of the questions, the language level to the participants, the time needed to answer the test. Some notes and changes were applied based on the feedback from the pilot study. The test time was calculated to be 16 minutes.

Second instrument: The 4Cs Soft skills survey

This survey was used to measure teachers' expressions and attitudes toward the 4Cs soft skills (communication and collaboration skills). It includes indicators grouped under the following categories:

1. Communication Skills
   - Expressing ideas clearly and effectively.
   - Using appropriate language for the audience.
   - Listening actively and responding thoughtfully.
- giving and receiving constructive feedback.

2. Collaboration Skills
   - Working effectively in teams.
   - Respecting diverse perspectives.
   - Sharing responsibilities and contributing equally.
-supporting team members.

The survey validity and reliability

The survey was designed to assess the communication and collaboration skills by the researcher. Furthermore, the survey was used at the end of the training program to assess teachers' attitudes toward communication and collaboration skills. The survey was developed after reviewing the previous studies related to communication and collaboration skills as they are considered from the 4Cs skills of the 21st century skills. The initial form of the survey included four communication sub skills and a number of their performance indicators.

The skills were rated according to a 3-point scale: not achieved, to some extent achieved, and achieved. The teachers' scores ranged from 1 (indicating lowest performance) to 3 (indicating highest performance). The survey items were reviewed by a specialist in the field of curriculum and instruction and psychologists. The viewers were asked to determine the appropriateness of the communication and collaboration skills to the science teachers. Feedback from supervisors and experts was used to refine the items. Few changes were applied to accommodate and approve the survey for further using.

Reliability was confirmed through statistical analysis to measure the reliability of the survey for communication and collaboration skills. The inter-rater reliability method was used as the survey list was checked by another rater beside the researcher. The agreement percentage was calculated between the two raters using Cooper equation and it was found to be 94% which is a good percentage. Thus, the survey was reliable.

The training program

The training program was structured according to the five stages of the design thinking Approach, and each stage was linked to specific educational activities and science lessons. The organization aimed to ensure that teachers could apply design thinking principles in planning and delivering their lessons. The training program was prepared according to the following steps:

First: The training program educational objectives:

- To enable teachers to apply design thinking in lesson planning.
- To foster critical and creative thinking in science education.
- To promote collaboration and communication among teachers.
- To encourage continuous reflection and improvement in teaching practices.

Second: The training program preparation as following:

1. The topics of pollutions of air, water, and earth were chosen, these topics considered as the most common problems that needs quick and creative solutions to solve. The topics were taught in 6 classes within two weeks.
2. The five stages of the Teaching professional program based on design thinking as following:
   - Empathize: understanding students' needs and challenges in learning science.
   - Define: identifying the core problems or learning gaps in science topics.
   - Ideate: brainstorming creative solutions and teaching strategies.
   - Prototype: designing lesson plans and activities that reflect innovative approaches.
   - Test: implementing the lessons in the classroom and evaluating their effectiveness.

3. Application Mechanism

The program was applied during teaching sessions and took two weeks. Teachers were guided to use the design thinking stages in planning and delivering science lessons.

4. Support Materials:

The researcher provided worksheets, planning templates, and reflection forms to help teachers document their process and evaluate their performance.

5. Evaluation:

The effectiveness of the program was assessed using the two tools:

- The 4Cs cognitive skills test.
- The 4Cs soft skills survey.

Third: The application of the training program was based on the following structure:

1. Introduction to the program:

The program begins by introducing teachers to the concept of design thinking, its stages, and its relevance to the topics of pollutions in water, air, and earth in science classes. The training program was organized according to the design thinking Approach, which includes five main stages: Empathize, Define, Ideate, Prototype, and Test. Each stage was linked to specific educational activities and lessons in science. The following table (2) summarizes the activities of design thinking stages:

Table 2 The activities of design thinking stages

Stages	Stage objective	activities
Empathize Stage	teachers were trained to understand the needs, interests, and challenges of learners in science.	Conducting interviews with students.
		Observing classroom behavior.
		Collecting feedback on previous science lessons.
Define Stage	Teachers analyzed the data collected during the empathize stage to identify core problems in geography learning	Formulate clear problem statements.
		Focus on specific learning difficulties.
		Prioritize issues based on student needs.
Ideate Stage	This stage involved brainstorming and generating creative solutions to the problems defined	Propose innovative teaching strategies.
		Use mind maps and idea boards.
		Collaborate in groups to refine ideas.
Prototype Stage	Teachers developed initial versions of lesson plans and teaching aids based on the ideas generated.	Designing interactive activities.
		Creating visual and digital materials.
		Preparing worksheets and evaluation tools
Test Stage	The prototypes were implemented in actual classroom settings	Delivered the lessons.
		Collected feedback from students and supervisors.
		Reflected on the effectiveness of their teaching strategies.

The researcher designed the model to align with the development of 4Cs skills among science teachers.

2. The researcher adapted the five stages of design thinking to suit the context of science education and the development of 4 Cs skills.

Results and Findings

After applying the teaching model based on the Design Thinking Approach, the researcher conducted statistical analysis to compare the results of the pretest and posttests for the 4Cs cognitive skills test then calculate the mean of the survey items. The findings are organized by the following research questions:

1. Are there statistical differences in participating science teachers on a training program based on design thinking to develop their 4Cs cognitive skills (critical thinking, creative thinking)?

The test was applied before and after the intervention. The (T) test was used to study the difference between the pre and post test. The results showed a statistically significant difference at the level of 0.05 in favor of the post-application scores, indicating improvement in the teachers' skills. The following table (3) summarizes the result of T test of critical and thinking skills test when N= 25 and df= 24 (the degrees of freedom).

Table 3 The result of T test of critical and thinking skills test

Test component	Pre- post test	Mean	Standard deviation	T test	sig
Creative thinking skills	pre	3.7	1.38	-8.156	.000
	post	7.13	1.54		
Critical thinking skills	pre	2.6	1.379	-15.360	.000
	post	7.56	1.04		
Both skills	pre	6.3	2.759	- 21.416	.000
	post	14.69	2.58		

The differences between the mean scores of the pre and post applications of the cognitive skills test in favor of the post application confirms the model's impact on skill development. The results showed a statistically significant improvement in the performance of the post test compared to the result of the pre test. The results are shown on the table (3) as following:

T test result for creative thinking skills is (-8.156) with (.000) significant, which indicates the significant difference between the mean of the pre and post test to the post test. T test result for critical thinking skills is (-15.360) with (.000) significant, which indicates the significant difference between the mean of the pre and post test to the post test.

The result of the study indicates the effectiveness of the teaching model based on the Design Thinking Approach in developing 4 Cs skills among teachers specializing in science. The researcher attributes the success of the model to its structured stages, which guides teachers through a process of exploration, innovation, and continuous improvement.

This improvement was evident in the following areas:

These findings are consistent with previous studies that emphasized the role of design thinking in improving creativity, and learner-centered teaching practices (Eden & Julie, 2020; Haryani et al, 2021; Veerasinghan et al, 2021; Ahmad et al, 2024). For instance, Eden and Julie (2020) found that while using design thinking, students applied various innovative ways in identifying and articulating a problem, learning logs, student-driven, and holistic assessments. Current study has found that teachers demonstrated enhanced ability to analyze and evaluate science information in the water, air, and earth pollutions topics. Teachers used design thinking stages to fosters critical thinking and competences explicitly by using a formalised process of constructive learning.

Also, there was a noticeable increase in the originality and diversity of ideas proposed by the students during lesson planning and classroom activities. That indicators of creativity improvement which agreed with previous studies such as Ladachart et al (2022). They identified important dimensions of design thinking mindsets that make such a difference. These dimensions include: (1) the orientation to learning by making and testing, and (2) the mindfulness to the process and impact on others. Veerasinghan et al (2021) suggested that the Design thinking approach fosters creative teaching in the chemistry classroom.

2. To what extent do science teachers participating on a training program based on design thinking develop the 4Cs soft skills (collaborative, and communication). The following table (4) summarizes the result of the survey components.

3.

Table 4 The result of the survey components

The survey component	Categories	Mean	Standard deviation
communication skills	Expressing ideas clearly and effectively.	2.59	0.820
	Using appropriate language for the audience.	2.58	0.624
	Listening actively and responding thoughtfully.	2.70	0.716
	Giving and receiving constructive feedback.	2.57	0.611
Total		2.61	0.693
Collaborative skills	Working effectively in teams.	2.76	0.788
	Respecting diverse perspectives.	2.80	0.823
	Sharing responsibilities and contributing equally.	2.77	0.651
	Supporting team members.	2.85	0.602
Total		2.795	0.716

The improvement in teachers' performance after applying the model reflects the impact of engaging them in meaningful learning experiences that are relevant to their context and interests. The survey results indicated improved interaction, teamwork, and clarity in communication among teachers. The results showed a statistically significant attitudes toward improvement in communication and collaboration skills. After calculating the descriptive analysis for the survey items on the 3- Likert scale options, the mean and standard deviation are shown on the table (4) as the following:

The mean for communication skills is (2.61) with a (0.693) standard deviation, which indicates the significant value for the items under the category of (Listening actively and responding thoughtfully). This category presents how actively teachers build relationship and trust between each other, make meaningful connection, and share insights and encouragement.

The mean for collaboration skills is (2.795) with a (0.716) standard deviation, which indicates the significant value for the items under the category of (Supporting team members.). This category presents the development of teachers' emotional support, recognition and encouragement of each other's, and workload assistance.

Current result supports the use of design thinking in education to promote social development and communication abilities. This finding confirms the results of many previous studies (Margarida, 2015; Noel & Liu, 2016; Tu et

al, 2018; Regina et al, 2020; Stith et al, 2020; Badr, 2021; Haryani et al, 2021). They found that design thinking facilitates students' communications and collaborative skills. For instance, Margarida (2015) observed that teams working on self-selected topics demonstrated superior communication and collaboration, attributing this to small-group development processes that helped members understand each other's preferences when choosing their project topic. Similarly, Stith et al. (2020) reported that students improved communication skills throughout the five stages of design thinking using oral, written, and artistic forms. Their study noted that group members began brainstorming collaboratively and providing feedback on solution originality and usefulness, though this required support. Students also learned to delegate tasks and recognize individual strengths within their teams during the process (Stith et al., 2020).

DISCUSSION AND CONCLUSION

The design thinking approach is based on a set of sequential and integrated stages that begin with understanding the learners and their needs, and end with testing and evaluating the proposed solutions. This structure allows learners to engage in a process of exploration, problem identification, idea generation, and solution development, which enhances their cognitive and practical skills. The application of the model provided teachers with opportunities to:

- Practice empathy by understanding the needs of their students.
- Define educational problems clearly and accurately.
- Generate innovative ideas for teaching geography.
- Design and implement lesson plans based on those ideas.
- Evaluate the effectiveness of their teaching and make improvements.

The researcher attributed these results to the nature of the design thinking model, which encourages creativity, and critical thinking development. The model allowed teachers to engage deeply with the learning process, reflect on their practices, and continuously improve their teaching strategies. Additionally, the model encouraged teachers to engage in reflective thinking, communication, and collaborative work, which are essential components of 21st-century education.

Recommendations

Based on the results of the study and the effectiveness of the teaching model built on the
Design Thinking Approach in developing 21st-century skills among science teachers, the researcher recommends the following:

1. Integrating design thinking stages into lesson planning and teaching strategies to encourage students to engage in deeper learning and reflective practices.
2. Developing educational curricula to include activities and tasks that align with the principles of design thinking, especially in subjects that require analysis, innovation, and practical application.
3. Providing workshops and professional development programs for in-service teachers in other specialties to familiarize them with design thinking and its applications in classroom settings.
4. Training faculty members in colleges of education on how to implement design thinking in their teaching and supervision of student-teachers.

Future research

1. Conducting further research on the use of design thinking in different educational contexts and its impact on various cognitive and non-cognitive skills.

REFERENCES

1. Ahmad, E. B., Almursy, S. F., Abdul Baqi, E. S., & Abdul Karem, S. M. (2024). A Training Program Based on Learning by Design Approach to Develop Planning Skills for Science Teacher Trainees. *Educational Research and Innovation Journal*. 4(13). ERIJ 2024.
2. Al-Amry, N.A., & Al-Abd Al-Kareem, R. H. (2024). The Role of a Design-Thinking-Based Instructional Strategy in Promoting 21st Century Skills. *Journal of Curriculum and Teaching Methodology*, 3(1), 54-71 https://doi.org/10.26389/ AJSRP.N121123
3. Badr, A. A. B. (2021). The Effect of a Proposed Blended Project-Based Learning Program on Developing the 4Cs Skills for Secondary Stage Students. *Faculty of Education Journal of Education*. Ain Shams University-Egypt. DOI: 10.12816/EDUSOHAG.2021. (ISSN 2536-9091)
4. Cohen, D. M. (2019). *Developing Students' Skills for the 21st Century: The National History Day Model as Academic Enrichment A Qualitative Case Study*. Drexel University.
5. Cook, K. L., & Bush, S. B. (2018). Design Thinking in Integrated STEAM Learning: Surveying the Landscape and Exploring Exemplars in Elementary Grades. *School Science and Mathematics*, *118*, 93–103.
6. Eden, H., & Julie, M. (2020). Teaching and Learning Design Thinking (DT): How Do Educators See DT Fitting into the Classroom? *Canadian Journal of Education / Revue canadienne de l'éducation*. 43:2 (2020). Canadian Society for the Study of Education/ www.cje-rce.ca

7. Erdoğan, V. (2019). Integrating 4C Skills of 21st Century into 4 Language Skills in EFL Classes. *International Journal of Education and Research*, 7(11), 120.
8. Geisinger, K. F. (2016). 21st Century Skills: What are they and how do we assess them? Applied Measurement in Education, 29(4), 245-249.
9. Haryani, E., Cobern, W. W., Pleasants, B. A-S., & Fetters, M. K. (2021). Analysis of Teachers' Resources for Integrating the Skills of Creativity and Innovation, Critical Thinking and Problem Solving, Collaboration, and Communication in Science Classroom. *Jurnal Pendidikan IPA Indonesia,* JPII 10 (1), 92-102 , DOI: 10.15294/jpii.v10i1.27084 , http://journal.unnes.ac.id/index.php/jpii
10. Hasso Plattner Institute of Design at Stanford University. (2022). *Design Thinking Bootleg*. Available online: https://dschool.stanford.e- du/resources/design-thinking-bootleg (accessed on 9 June (2022).
11. IDEO. (2022). *Design Thinking for Educators Toolkit* (2nd ed.). Available online: https://designthinkingforeducators.com/toolkit/ (accessed on 9 June 2022).
12. Kelly, T. R., & Knowles, J. G. (2016). A Conceptual Framework of Integrated STEM Education. *International Journal of STEM Education*, 3(11). https://doi.org/10.1186/s40594-016-0046-z.
13. Ladachart, L., Radchanet, V., & Phothong, W. (2022). Design Thinking Mindsets Facilitating Students' Learning of Scientific Concepts in Design-Based Activities. *Journal of Turkish Science Education*, 19(1), 1-16. DOI no: 10.36681/tused.2021.106. ISSN: 1304-6020, http://www.tused.org
14. Li, T., and Zhan, Z. (2022). A Systematic Review on Design Thinking Integrated Learning in K-12 Education. *Appl. Sci.,* 12(16), 8077; https://doi.org/10.3390.app12168077. Special issue STEAM Education and the Innovative Pedagogies in the Intelligence Era
15. Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, R. A. (2019). Design and design thinking in STEM Education. Springer Nature Switzerland AG 2019. *Journal of STEM Education Research,* 2(2), 93-104. https://doi.org/10.1007/s41979-019-00020-z
16. Margarida, R. (2015). Digital Game Design as a Complex Learning Activity for Developing the 4Cs Skills: Communication, Collaboration, Creativity and Critical thinking. *International conference on games and learning alliance, Springer.*
17. Morgan, M. L. (2015). *Developing 21st centurySskills Through Gameplay: To what extent are young people who play the online computer game Minecraft acquiring and developing media literacy and the Four Cs skills?* New England College.
18. Noel, L., & Liu, T. (2016). Using Design Thinking to Create a New Education Paradigm for Elementary Level Children for Higher Student Engagement and Success, in Lloyd, P. and Bohemia, E. (eds.), *Future Focused Thinking - DRS International Conference 2016*, 27 - 30 June, Brighton, United Kingdom. https://doi.org/ 10.21606/drs.2016.200
19. Prayogi, S., Raden, F. P. A., Rachid, E. Y., Kuang-Chih, T., and Hisbulloh, A. (2023). The Analysis of Students' Design Thinking in Inquiry-Based Learning in Routine University Science Courses , *International Journal of Essential Competencies in Education*, *2*(1), 1-14. https://doi.org/10.36312/ijece.v2i1.1338
20. Regina, P., McCurdy, M., & Bush, S. (2020). Problem-Based Design Thinking Tasks: Engaging Student Empathy in STEM , *Electronic journal for Research in Science and Mathematics Education,* 24(2), 22-55
21. Rox, L. (2017). Design Thinking in Education: A Critical Review of Literature Conference Paper · May 24-26, 2017 Bangkok, Thailand. https://www.researchgate.net/publication/324684320, IACSSM, *International Academic Conference on Social, ACEP ,Sciences and ManagementAsian Conference on Education and Psychology*
22. Skaggs, P. (2018). Design Thinking: Empathy through Observation, Experience, and Inquiry. In E. Langran & J. Borup, (Eds.), *Proceedings of Society for Information Technology& Teacher Education International Conference* (1168– 1172). Washington, D.C., United States
23. Snape, P. (2017). Enduring learning: Integrating C21st soft skills through Technology Education. *Design and Technology Education, 22*(3), 1-13.
24. Stith, K. M., Potts, M. L., DaVia Rubenstein, L., Shively, K. L., & Spoon, R. (2020). "Perceptions of K-12 Teachers on the Cognitive, Affective, and Conative Functionalities of Gifted Students Engaged in Design Thinking," *Journal of STEM Teacher Education:* 55(1) , Article 5. Available at: https://ir.library.illinoisstate.edu/jste/vol55/iss1/5
25. Teddlie, C., & Taskakkori, C. (2009). *Foundations of Mixed Methods Research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Thousand Oaks, CA: SAGE.
26. Tu, J-C., Liu, L-X., & Wu, K-Y. (2018). Study on the Learning Effectiveness of Stanford Design Thinking in Integrated Design Education . *Sustainability* 2018, *10*, 2649; doi:10.3390/su10082649 www.mdpi.com/journal/sustainability
27. UNESCO-UNEVOC. (2022). *21st Century Skills.* In TVETipedia Glossary. Retrieved from https://unevoc.unesco.org/home/tvetipedia+glossary/lang=en/show=term/term=21st+century+skills
28. Van Roekel, D., & Association, N. E. (2014). Preparing 21st century Students for a Global Society: an educator"s guide to the "Four Cs.". *National Education Association.*
29. Veerasinghan, K., Balakrishnan, B., Damanhuri, M. I. M., & Gengatharan, K. (2021). Design Thinking for Creative Teaching of Chemistry. *International Journal of Academic Research in Business and Social Sciences*, *11*(3), 670-687.

30. Watson, A. D. (2015). Design Thinking for Life. *Art Education*, *68*(3), 12–18. Retrieved fromhttp://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ106038 2&lang=de&site=edslive&authtype=ip,uid\nhttp://www.arteducators.org/research/ art-education
31. Wright, N., & Wrigley, C. (2019). Broadening Design-led Education Horizons: Conceptual insights and future research directions. *International Journal of Technology and Design Education*, 29, 1–2