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International Journal of Curriculum and Instruction 17(2) (2025) 572–593

IJCI
International Journal of Curriculum and Instruction

Implementing 21st Century Skills through the Future Classroom Lab (FCL) Model: A Case Study of an Environmental Education and Climate Change Course

Sibel Kızılışıkoğlu [a1], Semra Mirici [b*]

[a] *Gazi University, Graduate School of Educational Sciences, Ankara Türkiye*
[b] *Gazi University, Gazi Faculty of Education, Department of Biology Education, Ankara, Türkiye*

Abstract

This study examines the impact of the Future Classroom Lab (FCL) model on the development of 21st-century skills within the context of an environmental education and climate change course. Employing a mixed-methods research design, the study integrates both quantitative and qualitative approaches. The quantitative component utilizes a pre-test and post-test control group experimental design, while the qualitative aspect incorporates semi-structured interviews with students and the implementing teacher. The findings indicate significant improvements in students' communication, collaboration, critical thinking, problem-solving, creativity, media literacy, and leadership skills. The results reveal that technology-supported and student-centered learning environments foster creativity, enhance digital literacy, and facilitate problem-solving abilities. The study further demonstrates that the FCL model effectively supports the integration of 21st-century skills into educational settings by promoting interactive, flexible, and technology-enhanced learning experiences. The research provides empirical evidence for the benefits of innovative classroom environments and offers recommendations for future implementations in educational contexts.

Keywords: Future classroom Lab, 21st-century skills, environmental education, digital literacy, innovation in education

1. Introduction

1.1. Introduction to the problem

One of the primary objectives of education is to simplify individuals' daily lives and prepare them for future professional careers and awareness about environmental concerns by facilitating in class and out of class activities. These issues represent one of the most significant challenges of the current century (Trilling & Fadel, 2009; PI & Sikhulile, 2025).

[1] Corresponding author: Semra Mirici. ORCID ID.: https://orcid.org/0000-0003-4999-8628
E-mail address: semramirici@gmail.com

Students can overcome future challenges and prepare for adult roles—such as entrepreneurs, volunteers, citizens, parents, employees, and managers—by engaging in both in-school and out-of-school learning activities within the educational system (Yalçın, 2018). In order to reach their full potential as adults, young individuals must develop not only cognitive skills—including language, mathematics, and other academic achievements—but also various non-cognitive skills that facilitate the application of these achievements (National Research Council, 2012). Affective and psychomotor skills are just as important as cognitive skills and can be developed within the school system (Yalçın, 2018).

Despite numerous studies and reports on 21st century skills by various organizations and researchers (International Society for Technology in Education [ISTE], 2019; World Economic Forum [WEF], 2016; Lai & Veiring, 2012; Koenig, 2011; Ministry of National Education [MEB], 2011; University of Phoenix, 2011; Assessment & Teaching of 21st Century Skills [ATC21S], 2010; European Union [EU], 2007; EnGauge, 2003; Dearing, 1997), the most widely accepted framework for 21st century skills has been developed by the U.S.-based, non-profit organization, the Partnership for 21st Century Learning. The 21st century skills proposed by the Partnership for 21st Century Learning are summarized in the visual presented in Figure 1. This theoretical framework, depicted as a rainbow, consists of 21st century skills, core subjects, 21st century themes, and support systems (Partnership for 21st Century Learning, 2019). These components clearly highlight the competencies prioritized in contemporary educational systems.

Figure 1. P21's Frameworks for 21st Century Learning (Source: Battelle For Kids, 2019)

Individuals striving for success in this century must possess the ability to think critically and solve problems, lead in the workplace, collaborate and work harmoniously with others, innovate, communicate effectively, and maintain their sense of curiosity and imagination (Wagner, 2008, as cited in Er, 2016).

The rapid development, production, and dissemination of information in the 21st century have necessitated swift changes in educational environments (Boyacı, 2011; Wagner, 2008). Given that students benefit from the education and training systems of

various countries, interact with individuals from diverse cultures, and utilize information and communication technologies (ICT) to demonstrate their collective knowledge production skills, there is a need to design schools in alignment with 21st century skills (Yavrutürk & İlhan, 2022; Scott, 2021; Boyacı, 2011). Therefore, it can be stated that one of the primary objectives of schools is to equip students with the necessary knowledge and skills to prepare them for the future. In this context, the "Future Classroom Lab" was established to support evolving teaching approaches by integrating 21st century skills into learning and teaching processes and encouraging the reorganization of various learning environments alongside traditional classrooms (EUN, 2021).

The rapid change and digital transformation brought about by the information age have made the evolution of educational environments inevitable. In this context, one of the initiatives aimed at making learning processes more flexible, student-centered, and innovative is the Future Classroom Lab (FCL) model. The Future Classroom Lab (FCL) is grounded in contemporary approaches such as student-centered learning, constructivism, experiential learning, collaborative learning, and the theory of multiple intelligences. Created by European Schoolnet, the Future Classroom Lab (FCL) serves as an inspiring learning environment where teachers, school leaders, teacher trainers, policymakers, and other stakeholders can explore innovative pedagogical practices, flexible learning spaces, educational equipment, and technologies (European Schoolnet, 2025). The Future Classroom consists of six distinct learning areas: production, interaction, presentation, investigation, collaboration, and development (EUN, 2021).

Figure 2. EUN Future Classroom Model (EUN, 2022).

In light of this information, our study aims to thoroughly examine the impact of the FCL model on the development of 21st-century skills by clearly defining its primary objective.

1.2. Purpose of the study

The purpose of this study is to demonstrate the impact of the Future Classroom Lab (FCL) model on the teaching of 21st century skills within the context of environmental education and climate change courses. Additionally, the study aims to examine students' perceptions of the FCL model, as well as the experiences and opinions of the implementing

teacher. To achieve the outlined objectives, the following research questions have been formulated.

Research Questions

- Is there a significant difference in 21st century skills between the experimental and control groups prior to the implementation?
- Is there a significant difference between the pre-test and post-test results of the experimental group following the implementation?
- Is there a significant difference between the pre-test and post-test results of the control group following the implementation?
- Is there a significant difference in 21st century skills between the experimental and control groups after the implementation?
- What are the perceptions of students who learned the "Environmental Issues" unit of the environmental education and climate change course through the FCL regarding the process?
- What are the experiences and opinions of the implementing teacher during this research process?

2. Method

2.1. Research design

In this study, a mixed research design incorporating both quantitative and qualitative data was employed. The mixed research design involves integrating qualitative and quantitative data, using both approaches together (Gay, Mills, & Airasian, 2012; Fraenkel, Wallen, & Hyun, 2012, as cited in Alkan et al., 2019). The primary purpose of using this method is to conduct the research in a more in-depth and comprehensive manner by leveraging the strengths of both approaches. According to Creswell and Plano Clark (2011), the combined use of quantitative and qualitative data in a research study facilitates a more comprehensive understanding of a phenomenon (as cited in Alkan et al., 2019, p. 566).

The sequential explanatory design method, one of the mixed methods, was employed in the research. In the sequential explanatory design method, the priority typically given to quantitative data, a characteristic of mixed methods, is emphasized. After analyzing the quantitative data, qualitative data are collected to enrich the dataset, and the results are interpreted in relation to one another (Creswell, 2003). In this context, the quantitative aspect of the research was designed using the pre-test-post-test control group experimental design. This design, one of the quantitative research methods, focuses on evaluating changes within topics in the applied groups or differences between group topics while allowing for comparisons in experimental studies (Karasar, 2005). On the qualitative aspect of the research, a case study design was adopted. A case study is a method aimed at examining a bounded system in detail and involves a systematic process of collecting information about how the system operates through multiple data collection tools (Chmiliar, 2010). Merriam (2013) defines a case study as an in-depth description and examination of a bounded system. According to Creswell (2007), a case study is a

qualitative research approach in which the researcher conducts an in-depth investigation of a limited number of cases over time using multiple sources, identifying situations and themes related to the case. In summary, the findings derived from the quantitative data in the sequential explanatory design were enriched through qualitative data collection, thereby addressing the research topic in a multidimensional manner.

2.2. Study group

The study group of this research consists of 54 eighth-grade students from Ticaret Odası Middle School in the Mamak district of Ankara. The quantitative aspect of the research includes two groups: the control group and the experimental group. These groups were determined through random assignment at the class level. Random assignment means that every individual participating in the research has an equal chance of being selected (Büyüköztürk et al., 2019). For the qualitative aspect, 11 students from the experimental group were selected using purposive sampling. The purpose of employing purposive sampling is to facilitate an in-depth examination of the information within the group (Yıldırım & Şimşek, 2000). Furthermore, the selected sample is considered to fully represent the research objectives (Tavşancıl & Aslan, 2001).

2.3. Data collection tools

In the quantitative aspect of the research, the Comprehensive 21st Century Skills Scale, developed by Kalemkuş and Bulut Özek (2022), was administered to both the experimental and control groups. For the qualitative aspect, a semi-structured interview form was used. The data collection tools employed are administered as given in Figure 3 below.

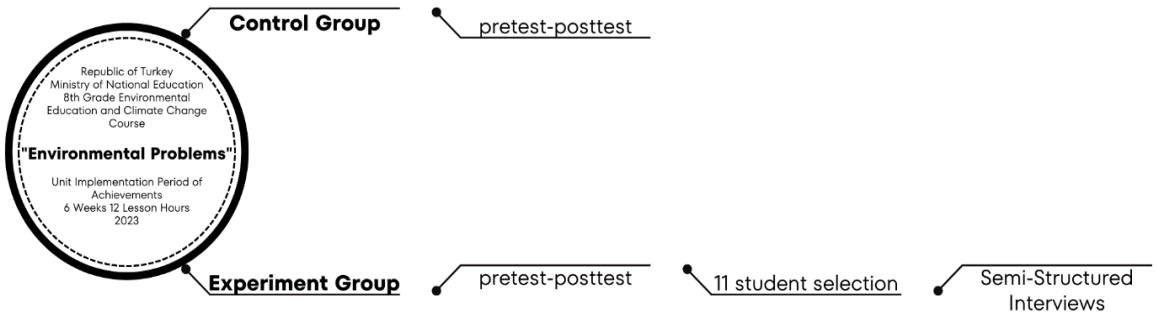

Figure 3. Data Collection Method

2.3.1. Comprehensive 21st century skills scale

This scale was designed by Kalemkuş and Bulut Özek (2022) to measure 21st century skills. The scale has been demonstrated to be adequate in terms of both validity and

reliability. The total variance explained by the scale is 59.771%, indicating that the scale effectively captures the skill factors. The reliability of the scale is also noteworthy. Specifically, the overall reliability coefficient (Cronbach's Alpha) is 0.973, and the reliability coefficients for each sub-factor exceed 0.60. According to Büyüköztürk (2004), a Cronbach's Alpha coefficient above 0.70 ensures reliability. Lastly, the t-test revealed that the discriminative power of the items is significant at the 0.01 level, indicating that the scale items can effectively distinguish between different skill levels.

2.3.2. Semi-structure interview form

The semi-structured interview method is a commonly used technique in qualitative research to explore participants' perspectives on the process (Yıldırım & Şimşek, 2006). The interview form used in this study was developed specifically by the researcher for this research. A question pool, created through a review of the literature, was presented to two subject matter experts for their feedback. Based on the feedback received, revisions were made, and the final version of the interview form was established.

2.4. Data analysis

The quantitative data were analysed using Kolmogorol-Simirnov, Shapiro-Wilk, Mann-Whitney U test and Wilcoxon Signed Ranks. The qualitative data were analysed via content analysis using a software called “transcriptor”.

3. Findings

Findings of the research are presented under two separate sub headings as Quantitative and Qualitative findings as in the following:

3.1. Quantitative findings

To assess the equivalence of the experimental and control groups in terms of 21st-century skills, the Comprehensive 21st Century Skills Scale was administered as a pre-test at the beginning of the research process. The same scale was then administered as a post-test at the conclusion of the training process. The pre-test and post-test analyses for the groups were conducted using the Mann-Whitney U test, while the Wilcoxon Signed Ranks test was applied to analyze within-group pre-test and post-test differences. The results of these analyses are presented in the tables below.

Table 1. Comprehensive 21st Century Skills Scale: Mann Whitney U Test for Pre-Test of Experimental and Control Groups

Sub-dimensions	Groups	N	Mean Rank	Sum of Ranks	U	p
Communication Skill	Experimental	27	30,61	826,50	280,50	,140
	Control	27	24,39	658,50		
Collaboration Skill	Experimental	27	28,67	774,00	333,00	,585
	Control	27	26,33	711,00		
Critical Thinking and Problem-Solving Skills	Experimental	27	28,00	756,00	351,00	,815
	Control	27	27,00	729,00		
Creativity and Innovation Skills	Experimental	27	28,81	778,00	329,00	,535
	Control	27	26,19	707,00		
Media Literacy Skills	Experimental	27	29,22	789,00	318,00	,420
	Control	27	25,78	696,00		
Information, Communication, and Technology (ICT) Literacy Skills	Experimental	27	29,15	787,00	320,00	,439
	Control	27	25,85	698,00		
Social Responsibility and Adaptability Skills	Experimental	27	27,80	750,50	356,50	,890
	Control	27	27,20	734,50		
Entrepreneurship and Self-Management Skills	Experimental	27	29,39	793,50	313,50	,370
	Control	27	25,61	691,50		
Leadership Skills	Experimental	27	30,41	821,00	286,00	,170
	Control	27	24,59	664,00		

According to Table 1, the mean ranks of the sub-dimensions for the experimental and control groups are similar, with the exception of leadership and communication skills. There is an approximate 5-point difference in the mean ranks for leadership (experimental group = 30.41; control group = 24.59) and communication skills (experimental group = 30.61; control group = 24.39). However, no statistically significant difference was found across all sub-dimensions ($p > 0.05$). This suggests that the experimental and control groups were equivalent in terms of 21st-century skills at the outset.

Table 2. Comprehensive 21st Century Skills Scale: Wilcoxon Signed Ranks Test for Pre-Test and Post-Test of Experimental Group

Sub-dimensions	Tests	N	Mean	Sd	Z	p
Communication Skill	Pre-Test	27	4,3333	,60624	-3,064	,002
	Post-Test	27	4,7531	,51964		
Collaboration Skill	Pre-Test	27	4,1185	,56910	-3,958	,000
	Post-Test	27	4,6593	,33657		
Critical Thinking and Problem-Solving Skills	Pre-Test	27	4,0185	,59885	-4,240	,000
	Post-Test	27	4,7068	,34851		
Creativity and Innovation Skills	Pre-Test	27	3,9506	,96389	-3,315	,000
	Post-Test	27	4,6296	,43690		
Media Literacy Skills	Pre-Test	27	3,8971	,84728	-4,202	,000
	Post-Test	27	4,7284	,30714		
Information, Communication, and Technology (ICT) Literacy Skills	Pre-Test	27	3,9947	,85758	-4,055	,000
	Post-Test	27	4,7302	,34389		
Social Responsibility and Adaptability Skills	Pre-Test	27	3,9444	,87767	-4,200	,000
	Post-Test	27	4,6759	,31380		
Entrepreneurship and Self-Management Skills	Pre-Test	27	3,8395	,83395	-4,017	,000
	Post-Test	27	4,6296	,39585		
Leadership Skills	Pre-Test	27	4,0000	,88192	-3,847	,000
	Post-Test	27	4,7531	,37659		

According to Table 2, the experimental group shows statistically significant differences in all sub-dimensions ($p < 0.05$), with the differences favoring the post-test results. These findings indicate that the experimental group was positively affected by the intervention and showed progress in 21st-century skills. When examining the average increases from pre-test to post-test in each sub-dimension, the results are as follows: communication skills: 9.7%; collaboration skills: 13.1%; critical thinking and problem-solving skills: 17.2%; creativity and innovation skills: 16.9%; media literacy skills: 21.3%; information, communication, and technology literacy skills, and social responsibility and adaptability skills: 18.5%; entrepreneurship and self-management skills: 20.6%; leadership skills: 18.7%. The findings show that students in the experimental group demonstrated the most improvement in media literacy skills (21.3%) and entrepreneurship and self-management skills (20.6%).

Table 3. Comprehensive 21st Century Skills Scale: Wilcoxon Signed Ranks Test for Pre-Test and Post-Test of Control Group

Sub-dimensions	Tests	N	Mean	Sd	Z	P
Communication Skill	Pre-Test	27	4,1111	,60624	-,578	,563
	Post-Test	27	4,0247	,56934		
Collaboration Skill	Pre-Test	27	4,0815	,39030	-,912	,362
	Post-Test	27	4,0259	,40439		
Critical Thinking and Problem-Solving Skills	Pre-Test	27	3,9383	,56121	-,338	,735
	Post-Test	27	3,9290	,45096		
Creativity and Innovation Skills	Pre-Test	27	3,8889	,66023	-,105	,916
	Post-Test	27	3,8889	,77349		
Media Literacy Skills	Pre-Test	27	3,7778	,70002	-,264	,792
	Post-Test	27	3,7942	,67706		
Information, Communication, and Technology (ICT) Literacy Skills	Pre-Test	27	3,9259	,71689	-,081	,935
	Post-Test	27	3,9206	,62689		
Social Responsibility and Adaptability Skills	Pre-Test	27	3,9537	,43995	-,873	,383
	Post-Test	27	4,0340	,38276		
Entrepreneurship and Self-Management Skills	Pre-Test	27	3,7654	,68447	-,282	,778
	Post-Test	27	3,7901	,75757		
Leadership Skills	Pre-Test	27	3,7778	,68563	-,429	,668
	Post-Test	27	3,8272	,72425		

According to Table 3, there is no statistically significant difference ($p > 0.05$) in any of the sub-dimensions for the control group. The mean scores of the pre-test and post-test are similar. Therefore, it can be concluded that the intervention did not impact the development of 21st-century skills in the control group.

Table 4. Comprehensive 21st Century Skills Scale: Mann Whitney U Test for Post-Test of Experimental and Control Groups

Sub-dimensions	Groups	N	Mean Rank	Sum of Ranks	U	p
Communication Skill	Experimental	27	37,15	1003,00	104,00	,001
	Control	27	17,85	482,00		
Collaboration Skill	Experimental	27	37,91	1023,50	83,50	,001
	Control	27	17,09	461,50		
Critical Thinking and Problem-Solving Skills	Experimental	27	38,83	1048,50	58,50	,001
	Control	27	16,17	436,50		
Creativity and Innovation Skills	Experimental	27	36,19	977,00	130,00	,001
	Control	27	18,81	508,00		

Media Literacy Skills	Experimental	27	38,78	1047,00	60,00	,001
	Control	27	16,22	438,00		
Information, Communication, and Technology (ICT) Literacy Skills	Experimental	27	38,59	1042,00	65,00	,001
	Control	27	16,41	443,00		
Social Responsibility and Adaptability Skills	Experimental	27	38,46	1038,50	68,50	,001
	Control	27	16,54	446,50		
Entrepreneurship and Self-Management Skills	Experimental	27	36,83	994,50	112,50	,001
	Control	27	18,17	490,50		
Leadership Skills	Experimental	27	37,72	1018,50	88,50	,001
	Control	27	17,28	466,50		

According to Table 4, the mean ranks for all sub-dimensions favor the experimental group. Additionally, there is a statistically significant difference ($p < 0.05$) in all sub-dimensions, favoring the experimental group. Therefore, it can be concluded that, at the end of the intervention, there is a significant difference in favor of the experimental group regarding 21st-century skills.

3.1.1. Qualitative research findings

3.1.1.1. Students' opinions on learning and innovation skills achievements

To assess the development of Learning and Innovation Skills, students were asked questions related to their communication and collaboration sub-skills, creativity and innovation sub-skills, and critical thinking and problem-solving sub-skills. These questions were as follows:

1. "What do you think were your responsibilities within the group activities in the FCL?"
   - "Did your peers fulfill their responsibilities to you and the group?"
   - "Were you able to utilize your skills during the activities?"
   - "If your peers did not fulfill these responsibilities, what should they have done?"
2. "How do you think processing the course in the FCL affected your creativity in the products you created? Can you explain with examples?"
3. "Following this course, what was the most important environmental issue for you, and what solution would you propose?"

Students reported that conducting lessons in the FCL enhanced collaboration, encouraged shared responsibility, fostered creativity through activities, allowed them to excel in certain tasks, and enabled them to effectively solve environmental problems.

Table 5. Students' Opinions on Learning and Innovation Skills Acquisition

Theme	Category	Code	Students	F	Sample Opinion
Learning and Innovation Skills	Communication and Collaboration Skills	Sharing Responsibility	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11	11	S1: *"I think I have taken on some technological responsibilities within the group.."*
		Avoiding Responsibility	S2-S3-S6	3	S2: *"...S3 fulfilled their responsibilities, and I believe I did too. However, I don't really think S8 and S7 did, because they were talking too much."*
		Standing Out	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11	11	S11: *"I usually handle the presentations, etc. My friends fulfilled their responsibilities towards me and other group members. I was able to stand out in some activities. You remember that thing we did with the green screen? I prepared the presentation for that.."*
	Creativity and Innovation Skills	Creativity and Innovation	S1-S3-S4-S5-S6-S8-S10	7	S6: *"I think it positively influenced my creativity. We can create any idea we want with the 3D printer.."*
	Problem-Solving and Critical Thinking Skills	Problem-Solving	S1-S2-S4-S6-S7-S8-S9-S10-S11	10	S1: *"Most likely, marine debris. I think there should be waste collection ships to gather this debris. There should also be a sensor for ghost nets thrown by pirates."*
		Critical Thinking	S3-S5	2	S3: *"Nuclear power; nuclear power is something that should both exist and not exist."*

The theme of learning and innovation skills comprises the categories of communication and collaboration skills, creativity and innovation skills, and problem-solving and critical thinking skills. The communication and collaboration category includes the codes of sharing responsibility (f=11), not sharing responsibility (f=3), and standing out (f=11); the creativity and innovation skills category includes the code of creativity (f=10); and the

problem-solving and critical thinking skills category includes the code of problem-solving (f=11) (Table 5).

3.1.1.2. Students' opinions on information, media, and technology skills achievements

To assess the development of information, media, and technology skills by the end of the implementation, students were asked questions related to their information literacy sub-skills, media literacy sub-skills, and information, communication, and technology sub-skills. These questions were as follows:

1. "*How did the technology-supported nature of this class and the frequent use of web tools affect your access to information?"*
2. *"Did you feel more comfortable answering your teacher's questions in a regular classroom or using a Web 2.0 tool like Slido in the FCL? Can you explain?"*
3. *"While conducting the course in the FCL, we used various technological materials (3D printer, VR glasses, green screen, digital microscope, Slido, storyboard, Canva, and other web tools). Which of these do you think was most effective, and why?"*

Through these questions, students indicated that the technology-supported nature of the FCL classroom and the use of web tools made accessing information easier *(Student 4: "It's easier. For example, searching for pages in books is more difficult. But on the internet, everything is at our fingertips."*). Students felt more comfortable answering questions using web tools, as everyone could communicate through writing, eliminating the need to raise hands and the fear of giving wrong answers (Student 9: *"...My peers don't hear it. I don't know who gave the answer. It provided a sense of comfort in that regard.*"). They also mentioned that not knowing who wrote their answers boosted their confidence and facilitated communication (Student 1: "*Here, through Slido. Because when you give a wrong answer to a regular teacher, there's a fear. The teacher asks you questions. The teacher becomes stressed, but this relieves that stress. You actually feel confident."*). Additionally, they found the use of different technological tools in the FCL engaging and effective for learning. Every student expressed that at least one technological tool captured their interest (Student 6: *"I think the 3D printer. Because we can create what we want, we can design.*").

Table 6. Students' Opinions on Information, Media, and Technology Skills Acquisition

Theme	Category	Subcategory	Code	Students	F	Sample Opinion
Information, Media, and Technology Theme	Media Literacy	Media Communication Tools	Tablet	S1-S5-S6-S8	4	S8: *"Normally, if I didn't have a phone or tablet, I would receive less information. But thanks to the tablet, I received more and faster information."*
			Internet	S2-S4	2	S4: *"It is easier. For example, searching for a page in books is more difficult. But on the internet, everything is at our fingertips."*
			Mobile Phone	S8	1	S8: *"Normally, if I didn't have a phone or tablet, I would receive less information."*
	Information Literacy		Feeling More Comfortable in Communication	S1-S2-S4-S5-S6-S7-S8-S9-S10	9	S9: *"From Slido. I feel more comfortable with it. My friends can't hear me. I don't know who gave the answer. It provided comfort in that sense."*
			Easy Access to Information	S1-S2-S3-S4-S5-S6-S7-S8-S9-S10-S11	1 1	S10: "*We can access information more easily and learn faster."*
	Information, Communication, and Technology Skills	Web 2.0 Tools	Canva	S7-S8	2	S5: *"Canva. Because we can access everything we want on Canva, and I think it is better compared to others."*
			Slido	S9-S11	2	S9: *"Slido. It is more comfortable. It is nice. It allows us to express ourselves."*
		Technological Tools	3D Printer	S1-S4-S6	3	S1: "*3D Printer. Because it is a tool that allows me to make anything I want. If you had a very large printer, you could even build a house with a 3D printer."*
			VR Headset	S7-S8	2	S8: *"Well, the headset had an impact. Because we also had our phones with us. The most important thing was that with the VR headset, everything came to life right before our eyes."*
			Digital Microscope	S2	1	S2: *"I think the digital microscope. For example, when it was explained in a regular lesson, in a science lesson, it didn't really become clear in my mind. The things being explained, like a round thing, called a cell, were described, but here I could actually see it."*

Based on the students' responses, the theme of information, media, and technology skills is categorized into three main areas: information literacy skills, media literacy skills, and information, communication, and technology skills. The media literacy skills category includes a subcategory for media communication tools, which consists of the following codes: tablet (f=4), internet (f=2), and phone (f=1). The information literacy skills category includes the following codes: communication through Slido (f=9), easy access to information (f=11), and feeling more comfortable (f=6). The information, communication, and technology skills category is divided into two subcategories: Web 2.0 tools and technological tools. The Web 2.0 tools subcategory includes Canva (f=2) and Slido (f=2), while the technological tools subcategory includes 3D printer (f=3), VR glasses (f=2), and digital microscope (f=1) (Table 6).

3.1.1.3. Students' opinions on life and career skills achievements

To assess the development of students' life and career skills, questions were asked about their social responsibility and adaptability sub-skills, entrepreneurship and self-management sub-skills, and leadership and responsibility sub-skills. The questions were as follows:

1. *"Did you face any difficulties using these technological tools? How did you feel?*"
    - "*Did you think there were areas where you needed to improve yourself?"*
    - *"How did you work within the group while using the technologies?"*
    - *"Was there anyone who took on a leadership role?"*
2. *"What kind of responsibilities did you have within the group activities in the FCL?"*
    - *"Did your peers fulfill their responsibilities to you and the group?"*
    - *"Were there any activities where you were able to stand out?"*
    - *"If your peers did not fulfill these responsibilities, what should they have done?"*
3. *"How did conducting this course in the FCL affect your individual responsibilities? Did it change your views on teamwork?"*

Most students reported having difficulties using technological tools (Student 1: *"… But I had some difficulties using the 3D printer*."), and identified areas where they needed to improve themselves (Student 4: *"… Yes, I thought there were areas where I needed to improve. For example, adjusting the printer settings takes a bit long."*). All students conducted self-assessments, spoke positively about teamwork, increased responsibilities, and shared leadership (Student 7: *"… There was no leader, teacher, everyone was the same."*). However, some students also mentioned experiencing difficulty working harmoniously with their groupmates (*Student 2: "My responsibility in the group was primarily to keep students like Student 8 and Student 7 quiet. Primarily Student 12. After that, you were teaching, and we were listening. Student 3 fulfilled their responsibilities, and I think I did too. But I don't think Student 8 and Student 7 did because they were talking too much."*).

Table7. Students' Opinions on Life and Career Skills

Theme	Category	Code	Students	F	Sample Opinion
Life and Career Skills	Entrepreneurship and Self-Management Skills	Self-Assessment	S1-S3-S4-S9-S10	5	S1: *"I didn't have much difficulty using technological tools because most of them were familiar to me. However, I experienced some difficulties when using the 3D source. Yes, I thought there were areas where I needed to improve myself, especially regarding 3D printers."*
	Leadership and Responsibility Skills	Self-Criticism	S1-S2-S4-S5-S6-S7-S8-S9-S11	9	S5: *"There were areas where I needed to improve myself, yes. Because, for example, I didn't have much interest in technology, but after taking the class here, it became more interesting to me."*
		Taking Responsibility	S1-S2-S4-S5-S8-S9-S11	9	S4: *"My individual responsibilities increased a bit. For example, group work used to be more difficult for me before. Now it has become easier."*
		Shared Leadership	S2-S3-S5-S6-S7-S8-S9-S10	7	S10 *"We worked equally in the group. Everyone had the right to speak. There was no one taking on a leadership role; everyone was equal."*
		Vertical Leadership	S1-S11	8	S1: *"I usually take on the leadership role. But I give importance to considering my friends' ideas because most of the good ideas come from them."*
	Social Responsibility and Adaptability Skills	Collaborative Teamwork	S1-S2-S3-S4-S6-S7-S8-S10-S11	8	S3 *"It didn't change my opinions within the group. It changed my perspective on teamwork. Yes, I worked better with close friends. I perhaps reached the problem more easily."*
		Incompatible Group Work	S2-S3-S6	3	S6: "*... It was S7 and S13 who did not fulfill their responsibilities. We could have done something separate for them; we could have prevented them from talking."*

According to the students' views, the theme of life and career skills consists of three categories: entrepreneurship and self-management skills, leadership and responsibility skills, and social responsibility and adaptability skills. The entrepreneurship and self-management skills category includes the codes of self-assessment (f=5) and self-criticism (f=9); the leadership and responsibility skills category include the codes of increased responsibility (f=7), shared leadership (f=8), and vertical leadership (f=2); and the social

responsibility and adaptability skills category includes the codes of harmonious teamwork (f=8) and disharmonious teamwork (f=3) (Table 7).

4. Discussion, Conclusion, and Recommendations

In this section, the findings obtained from the analysis of quantitative and qualitative data are interpreted according to the sub-dimensions of 21st century skills.

4.1. Sub-dimensions of 21st-century learning innovation skills

An analysis of the average pre-test and post-test scores revealed a 9.7% increase in the communication skills subdimension, a 13.1% increase in the collaboration skills subdimension, a 17.2% increase in the critical thinking and problem-solving skills subdimension, and a 16.9% increase in the creativity and innovation skills subdimension. These findings were further supported by semi-structured interviews conducted with students, some of which are presented below:

Student 1: "*It made a significant difference for me because, in traditional classrooms, participation is often challenging. Many students, including myself, feel hesitant to raise their hands or speak due to embarrassment. However, with FCL tablets, responses remain anonymous, which eliminates this fear and encourages participation*."

These results suggest that FCL transforms the learning environment through innovative approaches, enhancing student engagement and experiences. However, further student perspectives and additional quantitative data could provide stronger support for these findings. Scott (2015) found that student-centered learning environments foster creativity, critical thinking, and problem-solving skills. Moreover, technology-supported group work enhances students' ability to generate innovative solutions. This highlights the role of creative thinking and digital tools in fostering originality within FCL settings. Kampylis & Berki (2014) emphasized that integrating technology into instructional processes is essential for fostering creativity and innovation, positively influencing both individual and collaborative work. Their study demonstrated that students' capacity for developing innovative ideas is significantly supported by digital tools, reinforcing the role of creative activities in student development within FCL. Voogt et al. (2013) concluded that collaborative learning environments strengthen students' innovative thinking skills, with group dynamics fostering creativity and technology use enhancing critical thinking and problem-solving abilities. Their findings align with the notion that collaboration and creativity are further developed through the use of digital tools in FCL. Binkley et al. (2012) highlighted the essential role of problem-solving, critical thinking, and creativity in acquiring 21st-century skills, arguing that these competencies can be cultivated more effectively within digital learning environments. Their study further supports the contribution of digital tools to these skills within FCL settings.

Overall, extensive research underscores the significance of FCL as an innovative learning environment that enhances students' creativity, critical thinking, and collaboration skills.

4.2. Sub-Dimensions of 21st-Century Information, Media, and Technology Skills

Among the sub-dimensions of information, media, and technology skills, a 21.3% increase was observed in the media literacy skills sub-dimension, while an 18.5% increase was noted in the information, communication, and technology literacy skills sub-dimension. The findings indicate that media literacy skills (21.3%) were the most positively affected 21st-century skills among students in the experimental group during the process. The responses provided by students in the semi-structured interview forms support these results, with some of these opinions presented below:

Student 1: "*It made a big difference for me because in regular classes, people take it a bit easier. They don't like it. People don't want to raise their hands. They don't want to speak; they are shy. For example, I'm shy too. But here in the FCL, when you speak through tablets, nobody knows who said it, so nobody feels embarrassed at all*."

Student 4: "*It's easier to access information. For example, searching for pages in books is more difficult. But on the internet, everything is at our fingertips*."

There are studies in the literature that present similar findings regarding the impact of the FCL on information, media, and technology skills:

Kampylis, Bocconi, & Punie (2013) found that technology-supported learning environments enhance students' media and technology literacy, enabling them to analyze information more quickly and develop more effective learning strategies. Taguma et al. (2018) noted that digital tools improve students' media and information literacy skills, increasing their independent thinking and the speed at which they access information. Redecker et al. (2011) emphasized that integrating digital technologies into learning processes not only accelerates information access but also strengthens students' media literacy skills, with technology-supported learning environments proving effective in developing these skills. Therefore, the positive views of students regarding the ease of information access and the use of digital tools in the FCL are consistent with these findings. Jenkins (2009) found that technology-supported learning environments enhance media literacy, improving students' abilities to create and share digital content. Students' comfort with accessing information and using media through digital tools in the FCL aligns with these findings. Livingstone (2014) highlighted the need to increase the use of digital tools in learning environments to foster media literacy. Moreover, he emphasized that media tools support skills in accessing information and verifying content. The ease of information access and media use provided by the FCL is supported by these findings.

In this context, the enhancement of information access, media literacy, and technology skills through the FCL is frequently emphasized in the literature, with the positive effects of technology-supported tools on these skills being particularly highlighted.

4.3. Sub-dimensions of 21st-century life and career skills

Among the sub-dimensions of 21st-century life and career skills, an 18.5% increase was observed in social responsibility and adaptability skills, a 20.6% increase in entrepreneurship and self-management skills, and an 18.7% increase in leadership skills. The findings indicate that media literacy skills (21.3%) and entrepreneurship and self-

management skills (20.6%) were the most positively impacted 21st-century skills among students in the experimental group. Some responses from the semi-structured interview forms that support these results are presented below:

Student 1: *"I didn't have much difficulty using the technological tools because most of them were familiar to me. However, I did face some challenges with the 3D printer. Yes, I thought there were areas where I needed to improve, especially regarding the 3D printers. It's a very large area with its own program, etc. I usually take on the leadership role, but I always make sure to consider my friends' ideas because most of the best ideas come from them."*

4.4. Looking at the literature that supports these results

Trilling and Fadel (2009) emphasized that life and career skills, such as collaboration, leadership, confidence, and responsibility, are essential in modern education. They also highlighted that technology-supported learning environments play a significant role in developing these skills. Sasson et al. (2021) associated technology-supported group work with increased confidence, leadership skills, and collaboration among students, showing that such environments foster more active and responsible individuals. Taguma (2018) stated that innovative learning environments leveraging digital technologies are crucial tools for teaching life skills, including leadership, teamwork, and problem-solving. Fullan and Langworthy (2014) emphasized that digital and innovative learning environments significantly influence the development of students' collaboration, critical thinking, and communication skills, with group work and leadership roles being notably enhanced in such settings. Redecker et al. (2011) pointed out that digital learning environments provide extensive opportunities for developing life and career skills, particularly strengthening leadership and teamwork abilities. Chu et al. (2021) found that innovative learning environments foster the development of 21st-century skills such as creativity, problem-solving, collaboration, and leadership, underscoring their importance for success in life and career. Kay et al. (2010) observed that group projects supported by digital tools enhance students' leadership and responsibility skills while also boosting their confidence. Dumont et al. (2010) noted that innovative and flexible learning environments bolster students' leadership skills and individual responsibilities, increasing their capacity to work collaboratively and achieve shared goals. These studies collectively highlight the effectiveness of innovative learning environments like the FCL in developing crucial life and career skills—such as collaboration, leadership, confidence, and responsibility—and emphasize the importance of these skills for both educational and professional success.

Finally, as part of a study conducted by the General Directorate of Innovation and Educational Technologies, plans are underway to establish innovative classrooms in 3,500 middle and high schools. Various research efforts are being conducted to assess the needs of space arrangements and technological infrastructure. The goal is for 500 of these schools to feature flexible, modular classrooms that are technology-enhanced and support student-centered active learning processes across all subjects. These classrooms will be designed and constructed to integrate digital tools that support the skills, competencies, and achievements outlined in the curricula. The aim is to create learning environments where digital technologies are actively used to facilitate collaboration and group work, equipping

students with essential 21st-century skills. These classrooms are expected to be equipped with state-of-the-art technologies, including 3D printers and robotic coding sets to support coding education (MEB, 2024). Thus, in studies like this, the concept of "future classrooms" defines the innovative educational spaces that schools need to develop in the near future. This model represents a flexible structure designed to broaden the scope of future classrooms. However, simply surrounding future classrooms with technology and flexible learning spaces will not be sufficient (Göçen et al., 2020). The principles of efficiency, equity, and creativity should also be emphasized in an ideal school system. Students should be educated using contemporary methods, such as scenario-based learning, and teachers should be supported through university education or professional development programs focused on technology-based teaching and flexible class management skills. There is a clear need for classrooms with these features in future schools, which will play a crucial role in shaping the student profiles necessary to meet the challenges of the 21st century and beyond (Göçen et al., 2020).

Based on the findings of this research, several recommendations have been made to guide future studies:

1. Schools should integrate the necessary technology and organize their physical spaces in alignment with the FCL model.
2. There should be continuous technological and professional development for teachers, and dedicated technology support teams should be established within schools.
3. Scenario pools should be created for each lesson and achievement to be used within the FCL framework.

Additionally, this study examined the impact of the FCL on 21st-century skills. Future research could explore the FCL's influence on academic success, scientific process skills, and other areas, offering valuable insights for the education sector. While this study focused on the FCL model within the context of the environment and climate change course, expanding research to include other academic subjects and themes would contribute to a more comprehensive understanding and broader application of the FCL model.

These recommendations represent critical steps to make future classroom laboratories more innovative, interactive, and student-centered. Such environments will support students in developing essential 21st-century skills, better preparing them for the future world.

5. Acknowledgement

This article has been generated from the PhD thesis of the first author titled "***The Influence of the Future Classroom Lab (FCL) Model in Environmental Education and Climate Change Course on Teaching 21st Century Skills***" supervised by the second author at Gazi University, Graduate School of Educational Sciences in 2025.

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