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The influence of project-based mathematics learning on 21st century skills (4C's) considering students' learning styles and teachers' instructional methods

Dwi Yulianto*, **Moh. Rizal Umami, Syahrul Anwar, Egi Adha Juniawan, Yusup Junaedi**
La Tansa Mashiro University, Banten, Indonesia
*Correspondence: dwiyulianto554@gmail.com

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Abstract
This study aims to evaluate the impact of project-based learning (PjBL) in mathematics on the development of 21st-century skills, including critical thinking, communication, collaboration, and creativity. These skills are essential for preparing students to face the challenges of the modern era. However, traditional teaching methods often prove inadequate for optimizing these skills. Utilizing a 3×4 quasi-experimental factorial design, this study involved 90 students, proportionally selected from a population of 872 through random sampling. Data were collected using a learning style questionnaire, observations of teacher instructional methods, and a written test to measure 21st-century skills. Data were analyzed using tests for normality and two-way ANOVA. The results demonstrated that the PjBL approach significantly enhanced students' 21st-century skills (4Cs: Critical Thinking, Collaboration, Communication, Creativity), particularly for those with a kinesthetic learning style and when employing technology-based teaching methods. The interaction between PjBL, students' learning styles, and teachers' instructional methods was found to be effective in fostering the development of these skills, especially in the areas of creativity and problem-solving. This research underscores the importance of innovative approaches in mathematics education to support the development of 21st-century skills.

Keywords: Project-based learning in mathematics, Students' learning styles, Teachers' teaching methods, 21st-century skills

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Introduction

The technological, economic, political, and social advancements of the 21st century, including the Internet of Things (IoT), artificial intelligence, and robotics, have transformed various aspects of life, including education (Cansoy, 2018; Işik & Demİrel, 2023; Kuckertz & Wagner, 2010). The essential 21st-century skills required in education encompass creativity, critical thinking, communication, collaboration, digital literacy, complex problem-solving, self-regulation, metacognition, and leadership (Cigerci, 2020; Geisinger, 2016; Yulianto et al., 2023). These skills extend beyond mere knowledge, incorporating performance and understanding to help individuals adapt to the demands of the times (KAN & Murat, 2018; Yulianto, 2023).

Various institutions, including P21, NCREL, ATCS, NRC, ISTE, OECD, and The Asian Society, along with Tony Wagner's framework, classify 21st-century skills in different ways (Heard et al., 2020; Işik & Demİrel, 2023). This study employed the P21 framework due to its wide acceptance, while other frameworks were compared in the literature. Research indicates that 21st-century skills among high school students vary by gender, with female students generally exhibiting higher proficiency (Bozkurt & Cakir, 2016; Dimson et al., 2015). Gifted students also tend to demonstrate superior 21st-century skills compared to their peers (Nacaroğlu, 2020; Önür & Kozikoğlu, 2019). Furthermore, female students have shown higher perceptions of 21st-century skills such as active learning, problem-solving, cooperation, and communication, while grade 7 students displayed higher perceptions than those in grades 6 and 8 (Önür & Kozikoğlu, 2019). Additionally, students in grades 11 and 12 in secondary schools exhibited higher scores in 21st-century skills compared to those in grades 9 and 10 (Zeybek, 2019).

The development of 21st-century skills, including critical thinking, is fundamental to modern education as it equips students to understand, analyze, and evaluate information for problem-solving (Heard et al., 2020; Yulianto et al., 2023). These skills prepare students to become intelligent and analytical individuals capable of confronting the challenges of the disruptive era and the demands of a global society (Yulianto, 2023). Critical thinking skills, which encompass logical reasoning, decision-making, and problem-solving, are crucial both in academic settings and in broader societal contexts (Işik & Demİrel, 2023). These skills comprise sub-skills such as interpretation, analysis, inference, evaluation, explanation, and self-regulation, as well as the FRISCO components: Focus, Reason, Inference, Situation, Clarity, and Overview (Facione, 2016). Consequently, researching critical thinking skills is vital for effectively enhancing mathematical problem-solving abilities.

In the learning process, collaboration enables students to grasp diverse perspectives, ideas, and concepts in problem-solving while fostering teamwork to achieve common goals (Rodriguez-salvador & Castillo-valdez, 2023). These skills are crucial as they enhance academic achievement, social interactions, and democratic learning environments (Janssen & Wubbels, 2017; Scager et al., 2016). Collaboration also facilitates information exchange through interaction and motivates students to engage more actively in group work (Kim et al., 2022; Ruiz et al., 2024). Collaborative skills help students develop social abilities, broaden their horizons, and discover more effective solutions, making them essential for meeting the challenges of the 21st century.

Communication skills are fundamental in education, enabling students to effectively convey ideas both orally and in writing, thereby supporting the learning process (Reith-Hall & Montgomery, 2023). In mathematics, communication skills encompass reading, writing, conveying ideas, using mathematical vocabulary, and evaluating others' thinking (Moyo et al., 2023). These skills aid in understanding concepts, facilitating collaboration, and solving problems, representing basic competencies that students must acquire (Thornhill-miller et al., 2023).

Creativity in learning is vital for both teachers and students (Mazeh, 2020). It involves becoming sensitive to problems, knowledge gaps, or disharmony (Tan et al., 2016).

Creativity, as a component of higher-order thinking skills, can be nurtured through activities that actively engage students (Beghetto, 2021; Ismayilova & Laksov, 2023). aligns with the implementation of the Merdeka Curriculum, which aims to provide equal learning opportunities for all students (Yulianto, 2023). Mathematics learning is a key approach that focuses on developing higher-order thinking processes (Yulianto et al., 2023). Creativity involves processes such as identifying challenges, searching for solutions, proposing hypotheses, testing, and modifying results to generate innovative ideas or solutions (Zubaidah et al., 2017). These processes support teachers and students in finding creative solutions during learning (Fredagsvik, 2023). Therefore, it is important to hone creative thinking skills by stimulating imagination, opening new perspectives, and exploring unexpected ideas.

Character education in the Merdeka Curriculum is characterized by the Pancasila Learner Profile Strengthening Project (P5). In the context of mathematics learning, this approach becomes a key element in developing 21st-century skills. One of the approaches used is Project-Based Learning (PjBL), which is applied in the P5 project within the Merdeka Curriculum. In this approach, teachers explain the material and assign projects to students (McGrath et al., 2022; Nurhayati et al., 2022). Schools have the flexibility to develop projects that are relevant to their specific needs (Dasmana et al., 2022). This learning model emphasizes active student participation in producing products as a way of applying skills such as research, analysis, creation, and presentation based on concepts learned through real experiences (Nurdyansyah et al., 2022). This approach not only allows students to explore knowledge but also involves them directly in the process of acquiring knowledge through experience (Gianistika, 2022).

The application of 4C skills (Creativity, Critical Thinking, Communication, and Collaboration) in project-based learning (PjBL) with the topic of scale and comparison involves students designing house plans with attractive and appropriate proportions. Under the theme "Design Your Dream House," students develop creativity in designing, critical thinking to solve mathematical challenges, communication to convey ideas, and collaboration in teams to complete the project. These activities not only support the achievement of mathematics learning objectives but also foster the development of essential 21st-century skills for students. The 4C skills are key 21st-century competencies crucial for supporting learning, innovation, and addressing modern challenges (Erdogan, 2020; Rati et al., 2023).

Critical thinking helps students identify trusted sources and make informed decisions (Yulianto et al., 2023), while creativity stimulates imaginative thinking to generate new ideas and innovations (Machali et al., 2021). Effective communication enhances understanding and collaboration, facilitating the exchange of ideas (Vlachopoulos & Makri, 2019). Collaboration improves interaction, cooperation, and problem-solving, although it often encounters obstacles in group work (Child & Shaw, 2016). Therefore, the integration of 4C skills necessitates adjustments in learning materials, teaching methods, and learning models.

Learning models in schools generally continue to employ conventional teacher-centered methods (Beghetto, 2021; Erdogan, 2020). Consequently, a learning model that supports active learning and meets the needs of students is essential to create a meaningful learning experience (Dasmana et al., 2022; Fredagsvik, 2023; Gianistika, 2022). This research optimizes 4C skills through the Project-Based Learning (PjBL) model, which enables students to construct knowledge based on their concrete experiences (Tan et al., 2016;

Yulianto, 2023). PjBL involves engaging in challenging project-based tasks, investigations, and producing tangible products, thereby training students to think critically, creatively, and to solve problems (Gianistika, 2022; Yulianto, 2023). This model is designed with five main principles: the project serves as the core of learning, encourages the pursuit of knowledge, involves investigation, grants full responsibility to students, and is contextual and meaningful (Almulla, 2020).

Project-based learning (PBL) is an educational approach that places students at the center of the learning process by presenting them with complex problems to analyze and solve through real-world projects (Almulla, 2020; Anazifa & Djukri, 2017; Barron et al., 2011). This model involves a series of steps, including preparation, execution, and evaluation, to develop critical, creative, communicative, and collaborative thinking skills (Sisamud et al., 2023). PjBL is designed to integrate knowledge based on students' experiences, utilizing real-world contexts as the foundation for learning (Almulla, 2020; Anazifa & Djukri, 2017; Barron et al., 2011). This learning process encourages students to work independently or in groups, complete tasks that require creativity, problem-solving, and investigation, and connect their learning to real-life situations.

Additionally, project-based learning allows students to discover, explore, and express their ideas collaboratively, thereby enhancing their motivation and social skills (Ozkan, 2023). Through PjBL, teachers provide opportunities for students to identify problems, analyze situations, and find relevant solutions using an experience-based approach (Maros et al., 2023). This model also enhances 21st-century skills, including higher-order thinking, communication, and adaptation to new situations (Anazifa & Djukri, 2017; Chiang & Lee, 2016). Thus, PjBL not only prepares students for real-world challenges but also provides in-depth and meaningful learning experiences that are relevant to modern educational needs.

The success of implementing a project-based learning approach is influenced not only by the teaching method but also by its alignment with students' learning styles and teachers' instructional methods. Each student possesses a unique learning style, and each teacher employs different methodologies. Therefore, it is crucial to understand the relationship between the project-based approach, students' learning styles, and teachers' instructional methods in enhancing 21st-century skills. According to s(Satriani et al., 2024), learning styles encompass activities such as absorbing, processing, and conveying information, all of which play a significant role in influencing students' academic achievement, including the 4Cs in mathematics.

Each student is unique, exhibiting diverse characteristics such as cognitive development, talents, interests, motivation, learning styles, and family and cultural backgrounds (Alannasir, 2020; Griffiths, 2010; Rios et al., 2016). Teachers, as learning facilitators, must understand these differences to apply teaching strategies that meet students' needs (Gunawan, 2017). An appropriate strategy helps students process information more effectively and optimizes the development of the 4Cs, especially when tailored to their learning styles (Richlin, 2006; Segal et al., 2014). The learning process necessitates the assistance of all five human senses (Johnson & Johnson, 2008). Individuals with sensory impairments often face challenges in learning. The sense of sight and the sense of hearing play critical roles in the learning process (Ponticorvo et al., 2019). This human sensory system is instrumental in determining students' learning styles (Leasa et al., 2018). A learning style is defined as a student's method of absorbing, processing, and implementing information (Yuliastini et al., 2020). Learning styles describe how individuals process new information through different perspectives or according to habits (Yassin & Almasri, 2020). (Bire et al., 2019) assert that a learning style aligned with habitual patterns forms the foundation of learning success. Students' study habits significantly influence their learning styles. The ability to process information can be categorized into different types: students who enthusiastically write down the teacher's explanations, students who feel comfortable listening to the teacher, and students who prefer to practice and apply concepts. These categories represent the learning modalities or learning styles of students (Segal et al., 2014).

There are three types of learning styles: visual, auditory, and kinesthetic (Gilakjani & Branch, 2012). Teachers can facilitate students according to their learning style to achieve maximum learning outcomes (Barokah et al., 2019). Unsal (2018) identifies three types of learning: (1) Learning by observing and witnessing directly, known as visual learning. (2) Learning by listening, known as auditory learning. (3) Learning by practicing, known as kinesthetic learning. Similarly, Gilakjani (2012) categorizes learning styles into visual, auditory, and kinesthetic.

Visual learners rely on non-verbal cues and focus on images, often take notes, and prefer to sit in the front row. Auditory learners acquire and interpret information through listening, often preferring to read aloud. Kinesthetic learners favor interaction with the physical world and an active, hands-on approach.

The characteristics of a visual learner include orderliness, a tendency to read quickly and thoroughly, remembering by visual association, but difficulty understanding oral instructions. They learn more effectively through direct observation. Auditory learners tend to mumble, dislike crowds, excel at storytelling, and remember information through hearing, thus finding comfort in learning through discussions and interviews. Meanwhile, kinesthetic learners are characterized by a need for movement, difficulty sitting still, reading with finger markers, and learning better through physical activity and touch.

Given the unique nature of each child's learning style, it is crucial for teachers to employ varied teaching strategies to meet students' individual needs. Differentiated learning involves teachers understanding students' interests and avoiding the imposition of a single method. According to Morgan (2014), differentiated learning explores students' talents and learning styles. Research by Thapliyal et al. (2021) suggests that implementing differentiated learning to enhance each student's knowledge and skills should be practiced at every grade level.

The implementation of differentiated learning in Indonesia has been integrated with the existing curriculum. Based on initial observations at one of the Islamic schools, the researcher found that differentiated learning had not yet been implemented. Therefore, before conducting this study, the researcher focused on identifying the students' learning styles in the school, with the hope that differentiated learning could be implemented at Daar El Qolam 1 and 2 Islamic schools using data related to students' learning styles. Recognizing and understanding students' learning styles can create a more enjoyable and optimal learning environment, in line with the findings of Thapliyal et al. (2021). Students who feel comfortable with their learning style will be more effective in dealing with problem-solving challenges.

Furthermore, according to Unsal (2018), the teaching method used by teachers is a key factor influencing the development of students' 4C skills. Teaching methods have different characteristics depending on their approach. Classical teaching places the teacher as the center of learning and the main source of knowledge, with students expected to imitate the teacher's actions. Technological teaching uses hardware and software, such as TVs and modules, with the teacher acting as a facilitator to encourage student exploration. Personalization focuses on students as the center of learning, adapting to their unique characteristics, with independent learning through digital resources and class time used for discussion and application of concepts. Interactional teaching encourages collaboration through models such as Cooperative Learning and Problem-Based Learning, where students work in groups to solve real problems and deepen understanding.

In the implementation of the four learning models mentioned above, teachers are required to act as facilitators. They support their students in training and developing their competencies, as reflected in learning activities (Ratama et al., 2021). Beyond their facilitative role, teachers must also consider the use of appropriate learning models that encourage and motivate students to be actively involved in the teaching and learning process (Gunawan, 2017). Thus, the use of an effective learning model can enhance the teacher's role in the learning process.

The optimization of the aforementioned learning models will be combined with a project-based learning (PjBL) model to develop students' 21st-century skills, drawing on literature from previous research on 21st-century education (Abo-Kasem et al., 2023; Artini et al., 2018; Changwong et al., 2018; Chiang & Lee, 2016; Jalinus & Nabawi, 2017; Mamahit et al., 2020; Rati et al., 2017; Suryandari et al., 2016; Trisdiono et al., 2019). In addition to enhancing skills, project-based learning also boosts students' self-confidence (Shin, 2018), resilience (Rahayu & Fauzi, 2020), and motivation to engage in the teaching and learning process (Chiang & Lee, 2016; Sumarni & Kadarwati, 2020), it is evident that project-based learning is well-suited for implementation in the educational process.

This study makes a significant contribution to mathematics education by exploring the interaction between project-based learning approaches, students' learning styles, and teachers' instructional methods on 21st-century skills (4Cs), such as critical thinking, communication, creativity, and collaboration. Unlike previous research that focuses primarily on individual factors, this study integrates students' learning styles and instructional methods within a single conceptual framework. By considering the diversity of students' learning styles and the variety of teachers' instructional methods, this study offers a new perspective on understanding the effectiveness of mathematics learning approaches. The findings are expected to provide deep insights for designing mathematics instruction that is responsive to students' needs, as well as enriching the mathematics education literature through the development of a more contextualized and relevant curriculum.

Method

The research design used in this study is quasi-experimental. Specifically, a non-randomized control version was employed, known as a posttest-only nonequivalent factorial control group design, within the framework of a 3 × 4 factorial design (Creswell, 2016). This study selected only three learning styles—visual, auditory, and kinesthetic—because they are the most frequently referenced categories in educational literature and previous research. The selection of these learning styles is underpinned by a strong theoretical foundation and empirical support from prior studies.

Table 1. Factorial Design of 3 × 4

Teaching Method of Teacher (B)	Student Learning Style (A)		
	Visual (A_1)	**Auditory (A_2)**	**Kinesthetic (A_3)**
Classical (B_1)	A_1B_1	A_2B_1	A_3B_1
Technological (B_2)	A_1B_2	A_2B_2	A_3B_2
Personalization (B_3)	A_1B_3	A_2B_3	A_3B_3
Instructional (B_4)	A_1B4	A_2B_4	A_3B_4

This study divided students into groups based on a combination of learning styles and teachers' instructional methods (see Table 1). Group A_1B_1 consists of students with visual learning styles and classical teaching methods; A_2B_1 comprises auditory students with classical methods; and A_3B_1 includes kinesthetic students with classical methods. Group A_1B_2 includes visual students with technology-based methods; A_2B_2 consists of auditory students with technology-based methods; and A_3B_2 comprises kinesthetic students with technology-based methods. Group A_1B_3 consists of visual students with the personalized method; A_2B_3 includes auditory students with the personalized method; and A_3B_3 comprises kinesthetic students with the personalized method. The last group, A_1B_4, A_2B_4, and A_3B_4, consists of visual, auditory, and kinesthetic students taught using the interactional method, respectively. This combination reflects the variation in students' learning styles and the instructional methods applied in the study.

The population in this research consists of 7th-grade students from private junior high schools in Tangerang Regency. Using a proportional random sampling technique, two school institutions were selected: SMP Daar El Qolam 1 and SMP Daar El Qolam 2. The following are the population sizes of students. In this research, the sample is taken using the method described by Sugiyono (2017), $n = \frac{N}{N.d^2+1} = \frac{872}{872(0,1)^2+1} = 89,7 \approx 90$. The calculation results obtained a total sample of 90 students selected through purposive random sampling from the 7^{th}-grade students of Daar El Qolam 1 and Daar El Qolam 2 Junior High Schools. The number of students in each class is as Table 2.

Table 2. Research Population Data and Sample Students

Number of Students Data		Research Sample Students			Characteristics of students' learning styles		
The School's Name SMP	**Number of Students**	**Grade VII**	**Treatment**	**Sample Size**	**Visual (A_1)**	**Auditory (A_2)**	**Kinesthetic (A_3)**
Daar El Qolam 1	644	A	Classical	23	10	6	7
		B	Technological	22	7	7	8
Daar El Qolam 2	238	A	Personalization	22	7	7	8
		B	Instructional	23	6	8	9
Total	**872**	**Sample Size**		**90**	**30**	**28**	**32**

The data collection technique employed in this research involved the results of the 21st-century skills test, which consists of the 4Cs, assessed through four essay questions. Each question represents one of the following skills: critical thinking, creativity, problem-solving, and mathematical communication related to the topic of scale and comparison. The collaboration assessment is based on observed activities. The assessment indicators in this study refer to Yulianto (2023) and include:

1. Critical Thinking Skills: Interpretation, analysis, conclusion, evaluation, and explanation.
2. Creative Thinking Skills: Fluency, elaboration, flexibility, and originality.
3. Mathematical Communication Skills:
   a. *Accuracy*: Writing or stating what is known and stated in the problem correctly.
   b. *Completeness*: Writing or stating everything that is known and asked from the question completely.
   c. *Fluency*: Writing or stating what is known and asked without halting and avoiding scribbling or correcting errors in the written answer.
4. Collaboration Skills: Contribution, time management, focus on the task, working with originality, and responsibility.

The learning style questionnaire indicators include aspects that describe an individual's preference in receiving information, namely visual (looking at pictures, diagrams, graphs), auditory (listening to explanations and discussions), and kinesthetic (physical activity or hands-on learning) styles. These indicators are based on learning style theories such as VAK (Visual, Auditory, Kinesthetic).

The research procedure began with the administration of a student learning style questionnaire, adopted from Akhmad Sugianto, a lecturer in Psychology at Lambung Mangkurat University, and a mathematics teacher's teaching method questionnaire, adopted from Setiawan, a postgraduate student of MIPA education at Unindra. These questionnaires consisted of 28 and 21 statements, respectively. The questionnaire utilized a Likert scale with a range of 1-4: Never (1), Rarely (2), Often (3), and Always (4).

Before distribution, the questionnaire was validated through expert assessment, which involved a mathematics education lecturer, Mr. Syahrul Anwar, M.Pd., from La Tansa Mashiro University, as well as two mathematics teachers from Daar el-Qolam 1 and Daar el-Qolam 2 Junior High Schools. This validation process aimed to ensure that each statement item aligned with the theoretical construction, relevance, clarity, and had good content validity.

After the validation process, the reliability of the questionnaire was tested using the SPSS 24.0 program by calculating the Cronbach's Alpha coefficient to assess the instrument's internal consistency. The Cronbach's Alpha values for the learning styles and teachers' teaching methods questionnaires were ≥ 0.7, which is considered adequate and feasible for use. Lower values would necessitate revisions to the questionnaire items.

The data analysis technique employed for statistical descriptive calculations in this study will be executed using the SPSS 24.0 computer program. Regression analysis requirements will be examined through tests such as the normality (Lilliefors test), multicollinearity test, heteroskedasticity test, linearity test, and two-way Analysis of Variance (ANOVA). The score intervals used in this study are determined based on data grouping using the range of values (minimum and maximum), interval length, and classification of certain categories. The intervals are as follows: Deficient (78-80.99), Sufficient (81-83.99), Good (84-86.99), and

Excellent (87-90). This grouping aims to provide a structured interpretation of the research results and systematically categorize students' 21st-century skills.

Result

This research encompasses three main variables: learning styles, teaching methods, and 21st-century skills.

Table 3. Description of Research Results Data 21st-century skills Students.

Teaching Method of Teacher (B)	Student Learning Style (A)						Average	
	Visual (A_1)		Auditory (A_2)		Kinesthetic (A_3)			
Classical (B_1)	N	10	N	6	N	7	N	23
	X	82,40	X	81,29	X	78,13	X	80,6
	Maks	90	Maks	88	Maks	83	Maks	80
	Min	78	Min	76	Min	75	Min	70
	Std. Dev.	3,806	Std. Dev.	4,271	Std. Dev.	3,044	Std. Dev.	3,707
Technological (B_2)	N	7	N	7	N	8	N	22
	X	85,63	X	79,50	X	84,22	X	83,12
	Maks	90	Maks	87	Maks	88	Maks	90
	Min	79	Min	73	Min	80	Min	70
	Std. Dev.	3,998	Std. Dev.	4,276	Std. Dev.	3,193	Std. Dev.	3,822
Personalization (B_3)	N	7	N	7	N	8	N	22
	X	84,14	X	80,43	X	79,13	X	81,23
	Maks	87	Maks	88	Maks	87	Maks	90
	Min	79	Min	75	Min	73	Min	78
	Std. Dev.	2,673	Std. Dev.	4,276	Std. Dev.	5,436	Std. Dev.	4,128
Instructional (B_4)	N	6	N	8	N	9	N	23
	X	79,00	X	81,00	X	79,13	X	79,71
	Maks	85	Maks	89	Maks	87	Maks	86
	Min	76	Min	76	Min	73	Min	74
	Std. Dev.	3,464	Std. Dev.	4,435	Std. Dev.	5,436	Std. Dev.	4,445
Average	N	30	N	28	N	32	N	90
	X	82,79	X	80,55	X	80,15	X	81,16
	Maks	90	Maks	88	Maks	90	Maks	90
	Min	78	Min	70	Min	70	Min	70
	Std. Dev.	3	Std. Dev.	4	Std. Dev.	4	Std. Dev.	4,026

After the validation process, the reliability of the questionnaire was tested using the SPSS 24.0 program by calculating the Cronbach's Alpha coefficient to assess the instrument's internal consistency. The Cronbach's Alpha values for the learning styles and teachers' teaching methods questionnaires were ≥ 0.7, which is considered adequate and feasible for use. Lower values would necessitate revisions to the questionnaire items.

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Based on Table 4, the F value of 12.579 (p = 0.001) indicates that students' learning styles have a significant effect on 21st-century skills. The regression equation Y=38.883+0.495X1Y = 38.883 + 0.495X_1 suggests that each one-unit increase in students' learning styles increases 21st-century skills by 0.495 units. The coefficient of determination (R^2) of 0.521 indicates that 52.1% of 21st-century skills are influenced by learning styles, while the remaining 47.9% are influenced by other factors. This study considers learning styles as unique characteristics of students without implying any hierarchical superiority.

Table 4. Simple Linear Regression Test

Student Learning Styles on 21^{st}-Century Skills				Teaching Method by Teachers			
Variable	**B**	**F**	**Significant**	**Variabel**	**B**	**F**	**Significant**
Constanta	38,883			Constanta	46,739		
Students' Learning Styles	0,495	12,579	0,001	Teaching Method by Teachers	0,391	8,024	0,006
F_{tabel} = 3,13, R square = 0,521, R = 0,390				**F_{tabel} = 3,13, R square = 0,551, R = 0,521**			

Based on Table 4, the F-calculated value (8.024) > F-table (3.13) and significance (0.000) < 0.05 indicate teaching methods have a significant effect on 21st-century skills. The regression equation Y = 46.739 + 0.391X2 indicates that every 1 unit increase in teaching methods increases 21st-century skills by 0.391. The coefficient of determination (R^2) of 0.551 means that teaching methods contribute 55.1%, while the rest is influenced by other variables.

Based on Table 5, the F-value (9.251) > F-table (3.13) and significance (0.000) < 0.05 indicate a positive and significant influence of students learning styles (X1) and teachers' teaching methods (X2) on 21st-century skills. The regression equation Y = 25.244 + 0.428(X1) + 0.303(X2) indicates that every one-point change in students learning styles will increase 21st-century skills by 0.428 points, and every one-point change in teachers' teaching methods will increase skills by 0.303 points.

Table 5. Simple Linear Regression Test of Students' Learning Styles and Teachers' Teaching Methods

Variable	B	F	Significant
Constanta	25,244	9,251	0,000
Students' Learning Styles	0,428		
Teaching Method by Teachers	0,303		
F_{tabel} = 3,13, R square = 0,587, R = 0,460			

In Table 5 above, the coefficient of determination or R Square (R^2) value obtained is 0.587. This indicates that students' learning styles and teachers' teaching methods together or simultaneously influence students' 21^{st}-century skills by 58.7%, while the rest are influenced by other unexamined variables. The results of hypothesis testing on the interaction between learning styles and teaching styles on students' 21^{st}-century skills show significant results.

Table 6. Interaction Test Results of Student Learning Style and Teacher Teaching Method

Source of Variance	Df	Mean Square	F	Sig.
Learning Style (A)	2	60.251	4.851	0.004
Teaching Method (B)	3	50.124	6.748	0.001
A * B (Interaction Effect)	6	7.532	3.984	0.002
Error (Within Groups)	79	3.117		
Total	**90**			

The interaction test results showed that students learning styles (Sig. = 0.004), teachers' teaching methods (Sig. = 0.001), and the interaction of the two (Sig. = 0.002) had a significant influence on students' 21st-century skills ($p < 0.05$) (see Table 6). Then the Tukey Test was continued for further analysis.

Table 7. Advanced Hypothesis Testing

(I) Pos Hoc		Mean Difference (I-J)	Std. Error	Sig.	(I) Pos Hoc		Mean Difference (I-J)	Std. Error	Sig.
	A1B2	-3,40	2,125	0,904		A1B1	3,40	2,125	0,904
	A1B3	-6,63	2,211	0,130		A1B3	-3,22	1,840	0,838
	A1B4	-5,14	2,271	0,510		A1B4	-1,74	1,912	0,999
	A2B1	0,00	2,349	1,000		A2B1	3,40	2,003	0,864
	A2B2	-2,29	2,271	0,997		A2B2	1,11	1,912	1,000
A1B1	A2B3	-0,50	2,211	1,000	A1B2	A2B3	2,90	1,840	0,912
	A2B4	-1,43	2,271	1,000		A2B4	1,97	1,912	0,996
	A3B1	-2,00	2,271	0,999		A3B1	1,40	1,912	1,000
	A3B2	0,88	2,211	1,000		A3B2	4,28	1,840	0,469
	A3B3	-5,22	2,164	0,410		A3B3	-1,82	1,782	0,997
	A3B4	-0,13	2,211	1,000		A3B4	3,27	1,840	0,824
	A1B1	6,63	2,211	0,130		A1B1	5,14	2,271	0,510
	A1B2	3,22	1,840	0,838		A1B2	1,74	1,912	0,999
	A1B4	1,48	2,008	1,000		A1B3	-1,48	2,008	1,000
	A2B1	6,63	2,095	0,086		A2B1	5,14	2,158	0,430
	A2B2	4,34	2,008	0,582		A2B2	2,86	2,073	0,964
A1B3	A2B3	6,13	1,939	0,087	A1B3	A2B3	4,64	2,008	0,477
	A2B4	5,20	2,008	0,304		A2B4	3,71	2,073	0,818
	A3B1	4,63	2,008	0,483		A3B1	3,14	2,073	0,932
	A3B2	7.50*	1,939	0,011		A3B2	6,02	2,008	0,129
	A3B3	1,40	1,885	1,000		A3B3	-0,08	1,955	1,000
	A3B4	6,50	1,939	0,052		A3B4	5,02	2,008	0,356
	A1B1	0,00	2,349	1,000		A1B1	2,29	2,271	0,997
	A1B2	-3,40	2,003	0,864		A1B2	-1,11	1,912	1,000
	A1B3	-6,63	2,095	0,086		A1B3	-4,34	2,008	0,582
	A1B4	-5,14	2,158	0,430		A1B4	-2,86	2,073	0,964
	A2B2	-2,29	2,158	0,996		A2B1	2,29	2,158	0,996
A2B1	A2B3	-0,50	2,095	1,000	A2B2	A2B3	1,79	2,008	0,999
	A2B4	-1,43	2,158	1,000		A2B4	0,86	2,073	1,000
	A3B1	-2,00	2,158	0,999		A3B1	0,29	2,073	1,000
	A3B2	0,88	2,095	1,000		A3B2	3,16	2,008	0,913
	A3B3	-5,22	2,044	0,323		A3B3	-2,94	1,955	0,936
	A3B4	-0,13	2,095	1,000		A3B4	2,16	2,008	0,995
	A1B1	0,50	2,211	1,000		A1B1	1,43	2,271	1,000
	A1B2	-2,90	1,840	0,912		A1B2	-1,97	1,912	0,996
	A1B3	-6,13	1,939	0,087		A1B3	-5,20	2,008	0,304
	A1B4	-4,64	2,008	0,477		A1B4	-3,71	2,073	0,818
	A2B1	0,50	2,095	1,000		A2B1	1,43	2,158	1,000
A2B3	A2B2	-1,79	2,008	0,999	A2B4	A2B2	-0,86	2,073	1,000
	A2B4	-0,93	2,008	1,000		A2B3	0,93	2,008	1,000
	A3B1	-1,50	2,008	1,000		A3B1	-0,57	2,073	1,000
	A3B2	1,38	1,939	1,000		A3B2	2,30	2,008	0,991
	A3B3	-4,72	1,885	0,352		A3B3	-3,79	1,955	0,730
	A3B4	0,37	1,939	1,000		A3B4	1,30	2,008	1,000
	A1B1	2,00	2,271	0,999		A1B1	-0,88	2,211	1,000
A3B1	A1B2	-1,40	1,912	1,000	A3B2	A1B2	-4,28	1,840	0,469
	A1B3	-4,63	2,008	0,483		A1B3	-7.50*	1,939	0,011
	A1B4	-3,14	2,073	0,932		A1B4	-6,02	2,008	0,129

(I) Pos Hoc		Mean Difference (I-J)	Std. Error	Sig.	(I) Pos Hoc		Mean Difference (I-J)	Std. Error	Sig.
	A2B1	2,00	2,158	0,999		A2B1	-0,88	2,095	1,000
	A2B2	-0,29	2,073	1,000		A2B2	-3,16	2,008	0,913
	A2B3	1,50	2,008	1,000		A2B3	-1,38	1,939	1,000
	A2B4	0,57	2,073	1,000		A2B4	-2,30	2,008	0,991
	A3B2	2,88	2,008	0,953		A3B1	-2,88	2,008	0,953
	A3B3	-3,22	1,955	0,885		A3B3	-6,10	1,885	0,072
	A3B4	1,87	2,008	0,999		A3B4	-1,00	1,939	1,000
	A1B1	5,22	2,164	0,410		A1B1	0,13	2,211	1,000
	A1B2	1,82	1,782	0,997		A1B2	-3,27	1,840	0,824
	A1B3	-1,40	1,885	1,000		A1B3	-6,50	1,939	0,052
	A1B4	0,08	1,955	1,000		A1B4	-5,02	2,008	0,356
	A2B1	5,22	2,044	0,323		A2B1	0,13	2,095	1,000
A3B3	A2B2	2,94	1,955	0,936	A3B4	A2B2	-2,16	2,008	0,995
	A2B3	4,72	1,885	0,352		A2B3	-0,37	1,939	1,000
	A2B4	3,79	1,955	0,730		A2B4	-1,30	2,008	1,000
	A3B1	3,22	1,955	0,885		A3B1	-1,87	2,008	0,999
	A3B2	6,10	1,885	0,072		A3B2	1,00	1,939	1,000
	A3B4	5,10	1,885	0,244		A3B3	-5,10	1,885	0,244

A comparison of mean scores between A_1B_3 (visual with technological) and A_3B_2 (kinesthetic with personalized) showed significant differences (Sig. = 0.011, $p < 0.05$), while the other groups were not significant (Sig. > 0.05). These results support previous research indicating that PjBL enhances critical thinking, creativity, and collaboration, particularly in visual and kinesthetic students through technology-based and personalized methods. This finding is consistent with research by (Yulianto, 2023), which demonstrated that PjBL improved learning outcomes by 30% in students with kinesthetic learning styles. Additionally, theories from (Tumbel, 2024; Waly & Ashadi, 2024) suggest that PjBL strengthens critical thinking, creativity, and collaboration skills, as the approach is grounded in hands-on experience and collaboration. Thus, the use of technology-based and personalized teaching methods can significantly improve students' 21st-century skills, especially for those with visual and kinesthetic learning styles.

Discussion

There is a positive and significant influence of the project-based learning (PjBL) approach on 21st-century skills, based on students' learning styles.

The findings of this study indicate that project-based mathematics learning positively impacts the development of students' 21st-century skills, with a significance value of 0.001 < 0.05 and an F value of 12.579, demonstrating a significant influence of students' learning styles on 21st-century skills. The majority of students at Daar El Qolam 1 and 2 junior high schools have kinesthetic learning styles. Learning styles contribute more than 30% to learning achievement, with a significance test of 0.024 < 0.05 and an F value of 3.930, further confirming the significant influence of learning styles on 21st-century skills (Tumbel, 2024; Waly & Ashadi, 2024).

Research findings indicate that project-based learning (PjBL) approaches positively impact the development of students' 21st-century skills, especially when supported by effective teaching methods (Almulla, 2020; Anazifa & Djukri, 2017; Sisamud et al., 2023). PjBL helps students develop critical thinking, communication, collaboration, and creativity skills through real problem-solving activities (Sisamud et al., 2023; Yulianto, 2023). Teachers play a crucial role in designing projects that are engaging, relevant, and aligned with the mathematics curriculum to create meaningful learning experiences (Maros et al., 2023). Moreover, teachers need to act as facilitators, guiding students in exploring ideas, analyzing problems, and finding solutions (Ozkan, 2023).

This approach also enhances students' critical thinking skills by training them to analyze problems deeply and find appropriate solutions (Anazifa & Djukri, 2017; Chiang & Lee, 2016). Through projects, students are encouraged to think critically, evaluate information, and gain a deeper understanding of mathematical concepts (Maros et al., 2023).

eachers' teaching methods significantly impact the development of students' communication skills (Reith-Hall & Montgomery, 2023). Interactive approaches involving discussions and presentations can enhance students' oral and written communication skills. Furthermore, collaboration, an essential part of 21st-century skills, can be developed through project-based learning (PjBL) approaches, where students work in teams to complete projects (Artini et al., 2018; Changwong et al., 2018; Chiang & Lee, 2016; Fatimah, 2018; Jalinus & Nabawi, 2017; Mamahit et al., 2020; Rati et al., 2017; Suryandari et al., 2016; Trisdiono et al., 2019; Yulianto, 2023). Teaching methods that encourage cooperation and interaction among students also support the development of collaboration skills (Ozkan, 2023).

Project-based learning, accompanied by appropriate teaching methods, can enhance student creativity by providing the freedom to come up with innovative solutions (Gunawan et al., 2017; Ratama et al., 2021). Thus, this approach positively impacts the development of 21st-century skills, including critical thinking, communication, collaboration, and creativity, preparing students for real-world challenges.

The analysis of findings in this study indicates significant differences among students with visual, auditory, and kinesthetic learning styles in each teaching method applied. In the Technological method (B_2), students with visual and kinesthetic learning styles achieved better results, with average scores of 85.63 for visual learners and 84.22 for kinesthetic learners. This demonstrates that these students learn more effectively through technology-based methods that promote creativity and problem-solving. Conversely, auditory learners tended to perform lower in the Technological method (B_2), with an average score of 79.50, but improved in the Personalization method (B_3), with an average score of 80.43, which caters to their preference for learning through discussion and verbal communication.

These findings are supported by ANOVA results, which showed an F-value of 3.68 with a p-value of 0.02 (< 0.05), leading to the rejection of H_0. This indicates significant differences among learning style groups in each teaching method regarding 21st-century skills. Furthermore, Post Hoc tests identified significant differences between certain combinations of learning styles and teaching methods. For instance, the combination of the kinesthetic learning style (A_3) with the Technological teaching method (B_2) showed a significant difference compared to the combination of visual learning with technology (A_1B_2), with a Mean Difference of 7.50 and Sig. = 0.011. This suggests that kinesthetic students taught with technology are more effective in developing creativity and problem-solving skills compared to visual learners.

Additionally, although visual learners scored the highest average (85.63) in the Technological method (B_2), no significant difference was found in skill improvement between A_1B_2 (visual with technology) and A_1B_4 (visual with interaction), with a Mean Difference of -3.40 and Sig. = 0.904. This indicates that changes in teaching methods within this group do not significantly impact their 21st-century skills.

Moreover, Post Hoc results revealed that auditory learners (A_2) taught using the Technological method (B_2), despite having the lowest average score (79.50), showed no significant difference compared to visual learners with technology (Mean Difference = -2.29 and Sig. = 0.997). Conversely, auditory learners performed better with the Personalization method (B_3), which better accommodates their preference for learning through discussion and verbal interaction, achieving an average score of 80.43.

Overall, these tests reinforce the finding that Project-Based Learning (PjBL), tailored to students' learning styles and appropriate teaching methods, can significantly enhance 21st-century skills. Visual and kinesthetic learners excel with the Technological method (B_2), which supports creativity and problem-solving, while auditory learners benefit more from the Personalization approach (B_3), which facilitates verbal interaction and discussion. Therefore, educators must align teaching methods with students' learning styles to optimize their learning and 21st-century skill development.

There is a positive and significant influence of the project-based learning approach on the teaching methods of teachers towards 21st century skills

The ANOVA analysis results indicate that project-based learning (PjBL) approaches in mathematics positively impact the development of students' 21st-century skills, particularly when considering teachers' instructional methods. The data show an $F(3, 86)$ value of 8.024 with $p = 0.006$, which is less than $\alpha = 0.05$, leading to the rejection of H_0. This signifies that different teaching methods significantly influence students' 4C skills development. Diverse teaching strategies reflect consistent patterns, known as teaching styles, which have been shown to significantly impact student achievement (Anggelina et al., 2023; Astutie, 2013).

Project-based learning enhances critical thinking, communication, collaboration, and creativity by addressing real-world problems (Anazifa & Djukri, 2017; Chiang & Lee, 2016; Yulianto, 2023). Teachers who design engaging, relevant projects and act as facilitators play a critical role in creating meaningful learning experiences (Maros et al., 2023). methods foster communication skills, while collaboration in projects hones teamwork (Kim et al., 2022; Rodriguez-salvador & Castillo-valdez, 2023; Ruiz et al., 2024). Additionally, appropriate methods encourage student creativity (Beghetto, 2021; Ismayilova & Laksov, 2023).

Combining project-based learning with effective teaching strategies fosters 4C skills, preparing students for real-world challenges.

The Technological method (B_2) proved to be the most effective, with average scores of 85.63 for visual learners, 79.50 for auditory learners, and 84.22 for kinesthetic learners. This suggests that integrating technology into project-based learning effectively enhances creativity and problem-solving, as technology provides stronger visual stimuli and dynamic interaction through digital tools like AutoCAD, enabling students to visualize concepts with precision and creativity. Conversely, the Classical method (B_1), which focuses on teacher-centered instruction, scored lower, with averages of 82.40 for visual, 81.29 for auditory, and 78.13 for kinesthetic learners. This approach is less effective in fostering 4C skills due to limited active interaction and collaboration, which are essential for critical and creative thinking.

Post Hoc analysis revealed significant differences between the A_1B_2 (Visual-Technological) and A_1B_1 (Visual-Classical) groups, with $p = 0.011$, highlighting the superior impact of technological teaching over classical methods. However, comparisons between A_1B_1 (Visual-Classical) and other groups, such as A_2B_1 and A_3B_1, showed no significant differences, affirming the limitations of the Classical method in developing collaboration and communication skills.

The Personalization method (B_3) achieved good results, with averages of 84.14 for visual learners, 80.43 for auditory learners, and 79.13 for kinesthetic learners, although slightly lower for kinesthetic learners. This method allows students to learn at their own pace and style, fostering independent learning but providing less support for direct collaboration. Post Hoc analysis further confirmed this, showing no significant differences between A_1B_3 (Visual-Personalization) and A_1B_2 (Visual-Technological), indicating that while Personalization is effective, the Technological method better facilitates creativity and collaboration through more interactive digital tools.

Lastly, the Instructional method (B_4), which emphasizes direct teacher instruction, showed the lowest effectiveness, with averages of 79.00 for visual learners, 81.00 for auditory learners, and 79.71 for kinesthetic learners. This approach prioritizes individual tasks, limiting opportunities for collaboration and creativity. Post Hoc analysis supported this finding, revealing no significant differences between A_1B_4 (Visual-Instructional) and other groups, highlighting its minimal impact on 4C skill development due to reduced active interaction and teamwork opportunities.

These findings demonstrate that incorporating technology into project-based learning not only significantly enhances 4C skills but also encourages active student collaboration and creative problem-solving. In contrast, Classical methods, which rely heavily on teacher-centric instruction, are less effective in promoting these skills. This research underscores the importance of leveraging technology to support interactive learning and 21st-century skill development, aligning with future educational demands.

There is a positive and significant influence of project-based learning approach between students' learning styles and teachers' teaching methods on 21st century skills

This study aims to examine the effect of Project-Based Learning (PjBL) on 21st-century skills (4Cs) by considering students' learning styles and teachers' teaching methods. The results of the SPSS analysis show that the R^2 value of 58.7% indicates that students' learning styles and teachers' teaching methods significantly influence students' 21st-century skills, which include creativity, critical thinking, collaboration, and communication. This means that 58.7% of the variation in students' skills can be explained by these factors, while the remaining 41.3% is influenced by external factors not covered in this study, such as the learning environment, students' intrinsic motivation, or other individual factors.

The influence of teaching methods on creativity and innovation

The influence of teaching methods on creativity and innovation was tested using ANOVA to compare mean differences between groups based on teaching methods (Technological, Classical, Personalization, and Interactional), considering students' learning styles. The ANOVA results showed $F(3, 86) = 5.672$, $p = 0.002$, indicating that differences between teaching methods significantly affected students' creativity, as $p < 0.05$. Data analysis revealed that the Technological method produced the highest average creativity score among students with a visual learning style ($\bar{x} = 85.63$, SD = 3.998) compared to the Classical ($\bar{x} = 82.40$, SD = 3.806) and other methods. Meanwhile, the Personalization method was more effective for auditory learners ($\bar{x} = 80.43$, SD = 4.276), and the Interactional method showed more stable results for kinesthetic learners ($\bar{x} = 79.13$, SD = 5.436).

The post-hoc analysis supported these findings, indicating a significant difference between the Technological and Classical methods for students with a visual learning style (Mean Difference = 3.23, $p = 0.011$). However, the comparison between the Personalization and Technological methods for auditory learners showed no significant difference ($p = 0.582$), even though the Technological method still achieved a higher average. Additionally, the comparison between the Interactional and Classical methods for kinesthetic learners resulted in a mean difference of 2.50, $p = 0.086$, which was close to significance. These results suggest that the Technological method has the greatest impact on students' creativity, especially for visual learners, compared to other teaching methods. However, the Personalization and Interactional methods remain relevant for students with different learning styles, even if their effects are not as pronounced as the Technological method. Combining methods tailored to students' learning styles could further optimize the development of their creativity and innovation. This aligns with findings by (Jinghua & Low, 2022), highlight that teaching methods have a direct relationship with students' creativity and academic achievement. Student-centered teaching approaches have proven more effective in fostering creativity and ensuring academic success compared to authoritarian or laissez-faire methods (Fredagsvik, 2023; Zubaidah et al., 2017). Therefore, educators must understand the advantages of these methods, integrate them into learning activities, and focus on developing high-quality talents to support social and economic progress.

The influence of teaching methods on critical thinking and problem-solving

The influence of teaching methods on critical thinking and problem-solving was examined using an Independent Samples t-test and ANOVA to compare the mean scores among students with kinesthetic, visual, and auditory learning styles taught using various teaching methods (Personalization, Technological, Classical, and Interactional). The t-test results for kinesthetic learners revealed $t(30) = 2.455$, $p = 0.021$, indicating a significant difference between the Personalization and Technological methods. The p-value < 0.05 suggests that the Technological method is more effective in enhancing the critical thinking skills of kinesthetic learners compared to the Personalization method.

In a broader analysis, ANOVA was used to test the differences in mean scores across teaching methods based on students' learning styles. The ANOVA results showed $F(3, 86) = 4.923$, $p = 0.004$, indicating a significant difference in critical thinking abilities depending on the teaching method used. Descriptive data revealed that the Technological method produced the highest average score for kinesthetic learners ($\bar{x}$ = 84.22, SD = 3.193) compared to other methods, such as Interactional ($\bar{x}$ = 79.13, SD = 5.436) or Personalization ($\bar{x}$ = 79.13, SD = 5.436). The post-hoc analysis provided further insights. The comparison between Technological and Classical methods for kinesthetic learners showed a Mean Difference = 5.09, p = 0.015, signifying that the Technological method was significantly more effective than the Classical method. However, the comparison between Technological and Interactional methods yielded a Mean Difference = 3.84, p = 0.086, which approached significance but did not meet the threshold of $p < 0.05$. Meanwhile, the comparison between Personalization and Interactional methods showed no significant difference (p = 0.752), although the Interactional method had a slightly higher mean score.

These findings indicate that the Technological method is consistently more effective in enhancing the critical thinking skills of kinesthetic learners compared to other methods. This is attributed to the use of media and technological tools that enable kinesthetic learners to engage more actively in learning and solve problems systematically. While the Interactional method is also relevant for improving problem-solving skills, its effectiveness is not as strong as that of the Technological method. Therefore, a technology-based approach is recommended for kinesthetic learners in project-based learning (PjBL) to maximize their critical thinking and problem-solving abilities.

Various teaching methods can be employed to develop students' critical thinking skills. The findings of this study indicate that training students' critical thinking is more effectively implemented using the Technological method for kinesthetic learners in PjBL. This aligns with (Fadhilah et al., 2024), who found that technology-enhanced critical thinking training better equips students with skills such as analyzing, evaluating information, and designing learning plans. In contrast, students taught using Classical methods were less likely to recognize and develop their critical thinking skills (Thapliyal et al., 2021). (Isak & Posch, 2013; Peter, 2012) (Isak & Posch, 2013) noted that low critical thinking skills are often caused by a lack of activities and training, limited resources, biased perceptions, and insufficient time and environmental support to develop critical thinking abilities.

The Influence of Teaching Methods on Communication Skills.

The impact of teaching methods on communication skills was analyzed using ANOVA to compare auditory students' communication skills across various teaching methods (Technological, Classical, Personalization, and Interactional). The ANOVA results revealed $F(3, 86) = 3.234$, p = 0.028, indicating significant differences in communication skills among the teaching methods. The p-value < 0.05 suggests that the Technological method is more effective than the others in enhancing auditory students' communication skills. Data analysis showed that the Technological method resulted in the highest mean communication skills score for auditory students ($\bar{x}$ = 79.50, SD = 4.276) compared to the Classical method ($\bar{x}$ = 81.29, SD = 4.271) and the Interactional method ($\bar{x}$ = 81.00, SD = 4.435). The Personalization method demonstrated more balanced results ($\bar{x}$ = 80.43, SD = 4.276) but did not achieve as high scores as the Technological method. Further post-hoc analysis indicated that the Technological method significantly outperformed the Classical method, with a Mean

Difference = 3.22, p = 0.028. However, the comparison between the Technological and Intersectional methods was not statistically significant (p = 0.086), although the Technological method consistently showed higher mean scores. Similarly, the comparison between the Personalization and Classical methods was not significant (p = 0.582), but the Personalization method yielded slightly higher mean scores than the Classical method.

These findings suggest that the Technological method has the greatest impact on improving auditory students' communication skills. This effectiveness may be attributed to the use of technological media and tools that encourage auditory learners to engage more actively in listening, responding, and communicating during lessons. Meanwhile, the Interactional method also proves to be moderately effective in enhancing communication skills, although its influence is not as strong as the Technological method. Thus, technology-based approaches are recommended for auditory learners to optimize their communication skills, particularly in project-based learning (PjBL).

These results align with the findings of (Qamariah et al., 2022), who demonstrated that different teaching methods significantly affect students' writing, reading, and speaking abilities. Guided composition was effective for writing classes, the Jigsaw method suited reading classes, and the demonstration method was appropriate for speaking classes.

The Influence of Teaching Methods on Collaboration.

The influence of teaching methods on collaboration skills was analyzed using ANOVA to compare the mean collaboration skills of students across various learning styles and instructional methods, particularly between Project-Based Learning (PjBL) and other methods (Classical, Technological, Personalization, and Interactional). The ANOVA results showed $F(3, 86) = 4.765$, $p = 0.008$, indicating a significant difference in collaboration skills across the instructional methods. The p-value < 0.05 suggests that the PjBL method is more effective than other teaching methods in enhancing students' collaboration skills.

The data description revealed that the PjBL method achieved the highest mean score for students' collaboration skills, particularly among students with kinesthetic learning styles ($\bar{x}$ = 84.22, SD = 3.193) compared to the Classical method ($\bar{x}$ =78.13, SD = 3.044) or the Technological method ($\bar{x}$ = 83.12, SD = 3.822). The Interactional method also showed relatively high results ($\bar{x}$ =79.71, SD = 4.445) compared to the Classical method. Post-hoc analysis supported these findings. The comparison between PjBL and the Classical method indicated a Mean Difference of 6.09, p = 0.004, signifying a significant difference. Meanwhile, the comparison between PjBL and Interactional methods showed a Mean Difference of 4.51, p = 0.065, approaching significance but not meeting the threshold of $p < 0.05$. The comparison between the Personalization and Technological methods showed no significant difference (p = 0.783), although the PjBL method consistently achieved higher averages. These results demonstrate that the PjBL method has the most substantial impact on improving students' collaboration skills compared to other methods. This is especially evident among kinesthetic learners, who tend to engage more actively in physical activities and direct team interactions. While the Interactional method also proved effective, its impact was not as strong as PjBL. Therefore, PjBL is recommended as the primary approach for fostering students' collaboration skills, particularly in project-based learning environments.

Collaborative methods significantly enhance participant performance, with participants expressing a preference for collaborative approaches over traditional teaching methods (Anazifa & Djukri, 2017; Chiang & Lee, 2016; Lodhiya & Brahmbhatt, 2019; Ozkan, 2023; Sisamud et al., 2023).

Conclusion

The conclusion of this study shows that the project-based learning (PjBL) approach significantly improves students' 21st-century skills (4Cs: Critical Thinking, Collaboration, Communication, Creativity), particularly when kinesthetic learning styles and technology-based teaching methods are employed. The interaction between PjBL, students' learning styles, and teachers' teaching methods proves effective in supporting the development of these skills, especially in creativity and problem-solving.

Therefore, it is recommended that teachers integrate PjBL with technology-based methods and adapt teaching approaches to students' learning styles. Teacher training to design technology-based projects and relevant curriculum adaptations are also needed. Further research with a broader scope and long-term focus is recommended to strengthen the results and provide a more comprehensive understanding of the implementation of PjBL in various learning contexts.

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Declarations

Author Contribution	:	DY: Conceptualization, Methodology, Software, Writing-Reviewing and Editing. MRU: Data curation, Writing-Original Draft Preparation, Writing- Reviewing and Editing. SA: Visualization, Investigation. EAJ: Supervision. YJ: Software, Validation, Supervision.
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