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ONLINE-BASED SCIENCE PROJECT LEARNING AS AN ELECTIVE INSTRUCTING MODEL TO IMPROVE THE COLLABORATIVE SKILLS OF ELEMENTARY STUDENTS

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ABSTRACT

In the era of Intelligent Society 5.0, collaborative skills, which can be defined as the ability to work effectively with others to achieve common goals, are essential competencies for students to thrive. Therefore, this study aims to explore the effectiveness of Online-based Science Project Learning (SPL) as a substitute instructional model for fostering collaborative skills among elementary school students. The study participants consisted of 75 elementary school fifth-grade students, distributed across three classes in Muhammadiyah Islamic Elementary School, Surabaya, East Java, Indonesia. It is important to comprehend that this examination was a replica of a preliminary test, and was conducted following the same methodology without the inclusion of a control group. The study design utilized a single-group approach, incorporating both a pretest and a posttest assessment. Furthermore, data analysis was conducted through paired t-test, n-gain calculation, and ANOVA using IBM SPSS version 25. The obtained results showed a statistically significant increase in the collective proficiency score of the observed students, as assessed at a 5% alpha level, after their engagement with the online-based Science Project Learning (SPL) model. Additionally, the average n-gains for the three grades were high, with no grade-level differences, and over 90% of the students responded positively to the online-based SPL Model teaching method. Based on these findings, it was concluded that online-based SPL models improved the collaborative work skills of the observed students. This study has several implications. First, it enhances the understanding of 21st-century life skills and abilities among elementary school teachers in Indonesia. Second, it suggests the potential for expanding the scope of the subject matter. Third, it underscores the importance of government collaborations in studies that prioritize the development of 4C skills, particularly collaboration, among students. Moreover, the study also emphasizes the necessity of online-based Science Project Learning (SPL) for scholars interested in remote learning, with a focus on examining the collaborative abilities and science learning outcomes of elementary students in virtual learning environments.

Keywords: completion rate and primary education; sustainable development education; technology education

INTRODUCTION

The 21st century is characterized by the era of Industry 4.0 and Society 5.0, in which human labor is increasingly supplemented or replaced by cyber-physical systems and intelligent robots powered by machines. Accordingly, individuals who thrive in this era possess cognitive abilities that meet the requirements of the contemporary-

technological landscape.[1,2] These cognitive abilities include skills such as critical thinking and problem-solving, creativity, collaboration, and communication, known as 4Cs.[3]

Challenges are a consistent aspect of human life, and this fact underscores the importance of instilling collaborative skills in students from an early age. Besides equipping abilities to tackle problems collectively, it is equally imperative to enable students to realize their full potential. In this context, the focus should shift from merely achieving high test scores to prioritizing learning, comprehension, and collaborative skills.[4] As rightly observed in previous studies, elementary school students would benefit significantly from these skills as they learn how to cooperate, communicate proficiently, and collaborate effectively to solve problems.[5,6]

Furthermore, collaborative skills are paramount for achieving success in the 21st century and these attributes can be cultivated and fostered efficiently in the elementary school setting.[7,8] Its growth can be facilitated by instilling a sense of purpose, providing structured collaborative skill instruction, organizing group work effectively, and commencing with manageable tasks. By doing so, teachers empower their students to collaborate efficiently to achieve their objectives.[9]

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[2] Wan Tur Tasnim Wan Husssin, Jamalludin Harun, and Nurbiha A. Shukor, "Online Interaction in Social Learning Environment towards Critical Thinking Skill: A Framework," *Journal of Technology and Science Education* 9, no. 1 (February 1, 2019): 4–12, https://doi.org/10.3926/jotse.544.

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[5] Poppy Anggraeni et al., *Why 6 Cs? The Urgency of Learning at Elementary School*, 2022, https://doi.org/10.2991/assehr.k.220303.008.

[6] Nor Azikin Mohd Omar, Zailani Jusoh, and Shaidatul Akma Adi Kasuma, "Malaysian University Undergraduates' Perceptions towards Comprehensive Online Instructions amidst COVID-19," *Universal Journal of Educational Research* 8, no. 12 (November 2020): 7131–40, https://doi.org/10.13189/ujer.2020.081280.

[7] Rosario Isabel Lavado-Antonio et al., "Development of the Evaluation of Teaching Performance in Basic Education," *Journal of Higher Education Theory and Practice* 24, no. 3 (March 7, 2024), https://doi.org/10.33423/jhetp.v24i3.6858.

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[9] Ilmawan Mustaqim et al., "Building the Foundation for Creativity and Collaboration: Knowledge Sharing Learning Models," *Jurnal Cakrawala Pendidikan* 43, no. 1 (February 27, 2024): 262–72, https://doi.org/10.21831/cp.v43i1.60380.

According to previous studies, these competencies constitute a vital component of the set of attributes necessary for nurturing future citizens.[10,11] This is primarily because collaborative skills have gained significance due to their role in expediting group work. These skills have been found to enable the coming together of students from diverse backgrounds and with various talents to collectively pursue a shared objective, capitalizing on their strengths and abilities.[12,13]

Collaborative learning enables students to participate in activities that naturally foster connections by encouraging their collective engagement in communal learning experiences as a unified group.[14,15] This approach emphatically influences learning results.[16,17] Indicators of collaborative skills include active participation in group discussions (commitment viewpoint); permitting companions to express their precise opinions/ideas (aspects of working successfully within the differing qualities of individuals); sharing tasks to attain learning objectives (commitment angle); and contributing ideas to solve problems (problem-solving perspectives).[18,19]

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[10] Andrew Kenneth Tolmie et al., "Social Effects of Collaborative Learning in Primary Schools," *Learning and Instruction* 20, no. 3 (2010): 177–91, https://doi.org/10.1016/j.learninstruc.2009.01.005.

[11] Linda S. Jones, Rhianna C. Rogers, and Mark Abendroth, "Analyzing Student Learning in Sustainability: An International Exchange Case Study," *Journal of Strategic Innovation and Sustainability* 16, no. 3 (August 12, 2021), https://doi.org/10.33423/jsis.v16i3.4445.

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[14] Aini Akmar Mohd Kasim et al., "Online Collaborative Performance in Group-Based Tasks among Learners of Higher Education," *Studies in English Language and Education* 9, no. 3 (September 15, 2022): 948–66, https://doi.org/10.24815/siele.v9i3.24861.

[15] Alexandra Kolm et al., "International Online Collaboration Competencies in Higher Education Students: A Systematic Review," *Journal of Studies in International Education* 26, no. 2 (May 1, 2022): 183–201, https://doi.org/10.1177/10283153211016272.

[16] Young Hoan Cho and Kenneth Y.T. Lim, "Effectiveness of Collaborative Learning with 3D Virtual Worlds," *British Journal of Educational Technology* 48, no. 1 (2017): 202–11, https://doi.org/10.1111/bjet.12356; Janet Quint and Barbara Condliffe, "Project-Based Learning: A Promising Approach to Improving Student Outcomes. Issue Focus.," *Mdrc*, no. January (2018).

[17] Janet Quint and Barbara Condliffe, "Project-Based Learning: A Promising Approach to Improving Student Outcomes. Issue Focus," *MDRC* (MDRC, January 2018), https://eric.ed.gov/?id=ED580907.

[18] Ishmatun Naila, "The Effectiveness of Science Project Learning Based on Entrepreneurship Model to Improve Elementary Students' Collaborative Skills," *Mimbar Sekolah Dasar* 7, no. 3 (2020): 348–61, https://doi.org/10.17509/mimbar-sd.v7i3.28676.

[19] Yuxin Lu and Charanjit Kaur Swaran Singh, "The Effectiveness of the PBL Teaching Model on the Achievement and Critical Thinking Skills Development of Chinese Undergraduate Students: A Systematic Review," *Journal of Higher Education Theory and Practice* 24, no. 3 (February 25, 2024), https://doi.org/10.33423/jhetp.v24i3.6841.

The Trends in International Mathematics and Science Study (TIMSS) categorizes the achievement of study participants into four levels namely low (400), medium (475), high (550), and advanced (625). Based on this data, it can be concluded that the performance of Indonesia falls within the low level. The 2011 TIMSS results placed Indonesia in a low-ranking position, even below Palestine, although the country has been in a state of continuous conflict. The results of the 2011 TIMSS are presented in Table 1 as follows:

Table 1
TIMSS Indonesia's Achievements in the field of science

	TIMSS 2011				**TIMSS 2015**			
SCIENCE	**Low**	**Medium**	**High**	**Advanced**	**Low**	**Medium**	**High**	**Advanced**
	54%	19%	3%	0%	54%	15%	6%	0%

Source: TIMSS 2011 & 2015

From Table 1, the pressing necessity to prioritize science education at the elementary school level can be observed. Science education is primarily important because it forms the cornerstone to establish a robust foundation in science and primes students for subsequent learning in STEM disciplines. It also helps students develop the 4C skills, which are essential for success in the working landscape of the 21st-century. Moreover, the results presented indirectly indicated that Indonesian students possess a relatively low level of 4C skills.

A previous study was conducted at a Private Primary School in Surabaya, East Java, Indonesia, on the perceptions of fifth-grade students towards the online science course. The obtained results showed that students lacked collaborative skills, as evidenced by pre-test scores ranging between 1-2 (out of a maximum score of 4) for each indicator. Furthermore, it was found that these skills were not adequately emphasized in the curriculum utilized by the observed school. These issues significantly and adversely affected the level at which students participate in the online lessons. These effects include limited student engagement in expressing their opinions, and a lack of social interactions in the interactive and collaborative aspects of the online course, resulting in students not being accustomed to working on projects, especially in an online learning environment. Based on this understanding, it is essential to prioritize the process of addressing and fostering the ability of students to collaborate effectively with each other.

An alternative solution to address these issues is to implement online-based Science Project Learning (SPL), a system designed with the specific goal of enhancing collaborative skills. According to several previous studies,[20,21,22] collaborative project-based learning is recognized as a component of several higher education advancements. This component has been observed to effectively motivate students and maintain their engagement in the learning process. Collaborative Project-Based Learning Strategies play a crucial role in empowering instructors to engage with and flexibly guide students. As stated in prior studies, this measure fosters the ability of students to generate independent solutions and ensures their efforts and activities remain in line with the learning objectives.[23,24,25,26] In addition to effective collaboration, it has been indicated that students should also cultivate essential skills in information retrieval, analysis, communication, and time management.[27,28,29]

The online-based SPL model epitomizes active and collaborative learning by encouraging students to construct their knowledge through projects, develop problem-

[20] Nuri Balta, "The Effect of Student Collaboration in Solving Physics Problems Using an Online Interactive Response System," *European Journal of Educational Research* 6, no. 3 (2017): 385–94, https://doi.org/10.12973/eu-jer.6.3.385.

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[24] Dawn Wallace, Rusty Juban, and Jamie Vicknair, "Success in the Online Classroom: Lessons Learned," *Journal of Higher Education Theory and Practice* 22, no. 7 (July 27, 2022), https://doi.org/10.33423/jhetp.v22i7.5279.

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[26] Jowati Juhary, "Digitising a Learning Activity: Challenges and Opportunities," *Journal of Higher Education Theory and Practice* 21, no. 12 (November 4, 2021), https://doi.org/10.33423/jhetp.v21i12.4694.

[27] Fumie Kato, "Enhancing Integrative Motivation: The Japanese-American Collaborative Learning Project," ed. Yvonne Xian-han Huang, *Cogent Education* 3, no. 1 (December 31, 2016): 1142361, https://doi.org/10.1080/2331186X.2016.1142361.

[28] Salman Zulfiqar et al., "Using Simulation System for Collaborative Learning to Enhance Learner's Performance," ed. Yvonne Xian-han Huang, *Cogent Education* 5, no. 1 (January 1, 2018): 1424678, https://doi.org/10.1080/2331186X.2018.1424678.

[29] Eisuke Saito et al., "Comparative Institutional Analysis of Participation in Collaborative Learning," ed. Luís Tinoca, *Cogent Education* 7, no. 1 (January 1, 2020): 1779556, https://doi.org/10.1080/2331186X.2020.1779556.

solving skills, and actively engage in the learning process, with the teacher serving as a facilitator rather than the primary source of information.[30,31] This learning model can be adapted for an online learning approach, especially in light of the recommendation by UNESCO. In this recommendation, the utilization of remote learning was emphasized and the development and availability of educational platforms that can enable schools and teachers to connect directly with students, even over long distances was underscored with the primary aim of addressing current educational challenges.[32,33] In this regard, Chakraborty identified several factors that contribute to creating an engaging learning experience for online learners. These factors include establishing and maintaining a positive learning environment, fostering a sense of learning community, offering timely and consistent feedback, and utilizing appropriate technology to deliver relevant content.[34,35]

The "Digital Reports 2020," published by We Are Social research in late January 2020, indicated that nearly 64% of the entire Indonesian population is connected to the internet. Based on this understanding, it can be concluded that online learning plays a crucial role in the current educational landscape. This environment incorporates various elements such as text, images, sounds, videos, animations, and simulations.[36,37]

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[30] Ishmatun Naila, "The Effectiveness of Science Project Learning Based on Entrepreneurship Model to Improve Elementary Students' Collaborative Skills," *Elementary School Forum (Mimbar Sekolah Dasar)* 7, no. 3 (December 2020): 348–61.

[31] Lijuan Wang, "Learning Attitudes Towards and Learning Experiences in Online Teaching During the Pandemic," *Journal of Higher Education Theory and Practice* 22, no. 2 (March 21, 2022), https://doi.org/10.33423/jhetp.v22i2.5059.

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[37] Consuelo Garcia and Jesús Privado, "Predicting Cooperative Work Satisfaction of Autonomous Groups Using a Wiki Tool in Higher Education," *Interactive Learning Environments* 31, no. 1 (January 2, 2023): 117–28, https://doi.org/10.1080/10494820.2020.1764590.

Additionally, apart from the contemporary websites of schools, numerous free online resources are available for and accessible to elementary school students. These include Zoom meetings, Microsoft Teams 365, and the Phet Simulator, which offer virtual learning experiences.[38] Microsoft Teams 365, in particular, is recognized as one of the top platforms for enhancing instructional performance.[39] This platform has been found to effectively help instructors save time, maintain well-organized classes, and enhance communication with students.[40,41]

Microsoft Teams 365 is better suited for higher-grade classes in elementary school and this is primarily because older students often benefit from practical, real-life applications in their learning.[42] In addition to Microsoft Teams 365 and Phet Simulator, teachers can further support students through direct, face-to-face applications like Zoom, Google Meet, WhatsApp Video Call, and other similar platforms.[43,44]

According to the 2011 TIMSS (Trends in International Mathematics and Science Study) report, Indonesia is ranked 38th out of 42 participating countries, with an average science score of 386, while the global average score stands at 500.[45,46] Furthermore, in the latest results, specifically TIMSS 2015, the country was placed 44th out of 49

[38] Zulema Kayry Pineda La Serna et al., "Virtual Education in Health Emergencies: Increasing the Use of Technology in University Education," *Journal of Higher Education Theory and Practice* 24, no. 3 (March 7, 2024), https://doi.org/10.33423/jhetp.v24i3.6856.

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participating countries.[47] These results indicated that the scores possessed by science students remained relatively low. This underscored the need for students, especially in higher-grade classes, to develop collaborative skills[48].

The core issue under examination in this study is the effectiveness of the online-based SPL model in conjunction with the pre-existing knowledge of the collaborative skills of fifth-grade elementary school students in science subjects during the academic year 2022/2023. In other words, the study aims to assess the effectiveness of the online-based SPL model in the context of the prior collaborative skills of fifth-grade elementary school students in the field of science.

RESEARCH METHODS

In this study, a repeated pre-experiment was conducted across three sample classes, with no control group. Before implementing the online-based SPL model, the observed students were made to participate in a collaborative skills assessment. Subsequently, after completing the SPL model, the students were re-evaluated using the same collaborative skills test based on the same material. The online-based SPL model consists of four key phases including active participation in group discussions; allowing peers to express opinions and ideas; sharing tasks to achieve learning objectives; and contributing ideas to solve problems.

The sample for this study comprised 75 students from an Elementary School in Surabaya, Indonesia. These students were distributed across three classes namely 5A (25 students), 5B (25 students), and 5C (25 students), all enrolled in science subjects for the academic year 2022/2023. Furthermore, a simple random sampling method was utilized, ensuring that every member of the population had an equal chance of being selected.

Before gathering the utilized data, the following preparations were carried out. Development of a research tool, which included educational materials like Instructional Implementation Plans, Student Activity Sheets, and Student Instructional Materials. Creation of educational tools, such as assessments of collaborative skills and questionnaires for students. In this regard, the questionnaires and observation sheets were

[47] Andreas Schleicher, "PISA 2018: Insights and Interpretations.," *OECD Publishing*, 2019.

[48] Chiu-Pin Lin et al., "Explorations of Two Approaches to Learning CT in a Game Environment for Elementary School Students," *Journal of Computers in Education* 9, no. 2 (2022): 261–90, https://doi.org/10.1007/s40692-021-00203-x.

designed with reference to a grid of collaboration skill indicators, which is presented in Table 2.

Table 2
Collaboration Skills Indicator Rubric

Aspects	1	2	3	4	Score
Contribution	In discussions, large or small groups do not give ideas and do not participate.	In discussions large or small groups rarely (only 1 time) give ideas. But few (only 1 time) participated.	In discussions large or often (only 2 times) gave ideas. But not often (only 2 times) contribute to participation.	In large or small group discussions very often (more than 2 times) give ideas that become references in the discussion. Able to lead discussions and often (more than 2 times) contribute to the group.	1-4
Time management	Not working on the task, causes the group to to extend the deadline.	The task is completed, but > 3 minutes late. This caused the group to extend the time limit.	Completed the task, but = 3 minutes late. so, it still did not cause the group to extend the deadline.	Completed the task on time or completed before the deadline time limit, thus never causing the group to extend the deadline.	1-4
Problem-solving	No attempt to find and provide answers to the problem and give all the tasks (relying) to others.	Rarely (only 1 time) makes an effort to find answers to problems and uses solutions initiated by others.	Often (only 2 times) make efforts to find answers to problems, but the solutions found are developed by others. problems, but the solutions found were	Very often (more than 2 times) make a clear effort to find answers to problems. clear effort to find and come up with their ideas to	1-4

Aspects	1	2	3	4	Score
			developed from other people's ideas.	answer the problem.	
Working with others	Not listening to others' opinions not helping others and does not participate in group work.	Rarely (only 1 time) listened to other people's opinions and rarely (only 1 time) helped others due to difficulties in group work.	Often (only 2 times) listened to others' opinions well and often (only 2 times) helped others, but did not facilitate group work.	Very often (more than more than 2 times) listen to other people's opinions well and (more than more than 2 times) help others to facilitate group work.	1-4
Inquiry Technique	Does not search for multiple sources (only focuses on one source) and does not record information.	Rarely seeks a variety of sources (only focuses on 2 sources) and records information, but not in detail.	Often seeks a variety of sources (focusing on only 3 sources) and always records information, but not in detail.	Very often seeks a variety of sources (focusing on more than 3 sources) and always records information in detail.	1-4

Source: Personal Document

In order to ensure the integrity and dependability of the instruments utilized in this study that are in line with the stipulated criteria, a validation sheet was submitted to two experts in the field of science education. The questions were designed specifically to assess collaborative skills and were structured around three key aspects, namely contribution, effective function within a diverse group, and problem-solving.[49]

Table 3
The Validity And Reliability Of The Study Instruments

Learning Tools	Validity	Category	Reliability (%)	Category
Instructional plans	3.87	Credible	84%	Consistent
Student’s Worksheets	3.97	Credible	86%	Consistent
Teaching Materials	3.91	Credible	86%	Consistent

[49] Naila, “The Effectiveness of Science Project Learning Based on Entrepreneurship Model to Improve Elementary Students’ Collaborative Skills,” 2020.

Learning Tools	Validity	Category	Reliability (%)	Category
Test Instruments	4	Credible	100%	Consistent

Source: Personal Document

Table 3 shows that the science education tools consist of lesson plans, student activity sheets, and student materials. These instruments have been found to possess a high degree of reliability and credibility. Based on this understanding, the resources were considered well-suited as learning instruments for the present study.

Before commencing data analysis, it was considered crucial to establish the intended meaning of the validity of an online-based SPL model. In this regard, the following criteria were considered for determining the success of an online SPL model; statistically significant increase in the average collaboration skill scores of students after implementing the online-based SPL at a 5% alpha level; achievement of at least moderate progress (average N-gain), which is considered the norm; absence of significant differences in the mean N-gains among the three experimental classes. To analyze the obtained data, quantitative descriptive and inferential statistics were leveraged. It is important to acknowledge that this dataset comprised results from student cooperation skills tests and responses from the administered questionnaires. The inferential statistical analysis, which was conducted using IBM SPSS 25, included techniques such as analysis of variance (ANOVA) or Kruskal-Wallis tests, paired t-tests or Wilcoxon tests, and N-gain calculations. Furthermore, a pairwise two-tailed test was conducted to assess whether the students effectively collaborated. This approach was applied using a specific formula to determine the extent of collaboration among the students. n-gain = (post-test score – pre-test score) / (maximum score – pre-test score), with the following criteria: n gain is considered high if its value equates to 0.7; medium if 0.3 < n gain < 0.7; and low if the value is equal to 0.3. Accordingly, analysis of variance (ANOVA) was utilized to determine whether there were significant differences in the average improvement of collaborative skills (n-gain) among students in the three grade levels. The test criteria are as follows:

H0 (Null Hypothesis): No significant difference exists between the collaborative skills of students who were learning science through online-based project learning and those who were not.

Ha (Alternative Hypothesis): Students who were learning science through online-based project learning have superior collaborative skills compared to those who do not.
In this study, the null hypothesis (H0) was rejected and this was primarily because the obtained value of sig(p) was 0.05, indicating that the average n-gain values across the three groups were not the same. However, it is important to establish that if this value was greater than 0.05, H0 would have been accepted.

RESULT AND DISCUSSION

The development of the online-based SPL model was influenced by both collaborative learning and project-based learning principles. As a result, the stages of the online-based SPL model were designed specifically in line with the characteristics of online learning activities. These stages were integrated into online learning (refer to Fig 1), facilitated through the Microsoft Teams platform, and included essential elements such as formulating initial questions, project planning, plan creation, progress monitoring, result evaluation, and experience assessment.[50,51]

Figure 1
The Online-Based SPL Stages
Source: Personal Document

[50] Dwi Sulisworo, "Designing the Online Collaborative Learning Using the Wikispaces," *International Journal of Emerging Technologies in Learning (iJET)* 7, no. 1 (February 29, 2012): 58–61, https://doi.org/10.3991/ijet.v7i1.1863.

[51] Abhishek Bhati and Insu Song, "New Methods for Collaborative Experiential Learning to Provide Personalised Formative Assessment," *International Journal of Emerging Technologies in Learning (iJET)* 14, no. 07 (April 11, 2019): 179–95, https://doi.org/10.3991/ijet.v14i07.9173.

The collected data consisted of the collaborative skills of students which was assessed through a pre-test and their final test results (post-test). It is essential to understand that the observed students were engaged in a pre-test before commencing their studies with the online learning system. Subsequently, after completing the learning process, a post-test was also conducted. Both the pre-test and post-test comprised essay questions as the assessment method. An overview of the collaborative skills of the observed students is presented in Table 4.

Table 4
Recapitulation Of Collaborative Skills Results

Class	Pretest	Posttest	N-Gain	Level
5A	66.9	83	0.56	Medium
5B	67.4	85.1	0.59	Medium
5C	65	85.3	0.61	Medium
Total	66.4	84.5	0.58	Medium

Source: Personal Document

To evaluate the collaborative skills of the students, a test instrument comprising 10 short-answer questions was utilized. From Table 4 above, it can be seen that the average assessment of the collaborative skills of the students increased in all classes. For instance, in class A, there was a 56% increase with an n-gain value of 0.56 while Class B witnessed an increase of 59%, represented by a 0.59 n-gain. Similarly, Class C experienced a 61% improvement, with a corresponding n-gain of 0.61. This study exclusively utilized an online SPL (Science Project Learning) model as the instructional approach. As rightly stated in a previous study, the SPL framework is centered on building new knowledge upon the existing level of expertise possessed by students. In this context, the role of the teacher is to serve as a guide and facilitator, enabling students to acquire knowledge through practical application.[52]

Levene's test was utilized with significance levels of 5% and 0.05 for conducting homogeneity tests on the initial (pre-test) and final (post-test) assessments,

[52] Rasmitadila Rasmitadila et al., "Limited Face-to-Face Learning on Students in Inclusive Classrooms during the Covid-19 Pandemic: Perceptions of Elementary School Teachers in Indonesia," *Cogent Education* 10, no. 1 (December 31, 2023): 2213612, https://doi.org/10.1080/2331186X.2023.2213612.

respectively,[53,54] In this context, if the p-value resulting from the test is greater than 0.05, it can be concluded that the distribution of the data is uniform or homogeneous. The homogeneity test results are presented in Table 5.

Table 5
Homogeneity Test Results

Variable	Significance	Standard	Data Variance
Pretest	0.068	0.05	Homogenous
Posttest	0.073	0.05	Homogenous

Source: Personal Document

As shown in Table 5, the homogeneity tests for both the pretest and posttest provided p-values that were significantly greater than 0.05 (5%). This indicated that the data variants in classes A, B, and C were homogeneous. In this study, the Kolmogorov-Smirnov test was used to assess normality, especially since a substantial portion of the data analyzed consisted of values that were equal to or greater than 50. Based on this understanding, the data distribution was considered valid only if the obtained p-value was greater than 0.05.[55] The outcomes of the normality test are shown in Table 6.

Table 6
Normality Test Results

Variable	Kolmogorov-Smirnov	Standard	Data Distribution
A Class	0,158	0,05	Normal
B Class	0,110	0,05	Normal
C Class	0,183	0,05	Normal

Source: Personal Document

The normality test carried out for the students in class A resulted in a score of 0.158, which is greater than the minimum threshold of 0.05. Accordingly, classes B and C achieved a score of 0.110 and 0.183 respectively, which is still above 0.05. This test was conducted on both the pre-test and post-test results, as well as on the collaborative skills test, the initial test, and the knowledge test. In this study, the data was considered to have a normal distribution since the Kolmogorov-Smirnov score exceeded 0.05 (at a 5% significance level). Therefore, the results of both homogeneity and normality tests for

[53] Duwi Priyatno, "Belajar Alat Analisis Data Dan Cara Pengolahannya Dengan SPSS," *Yogyakarta: Gava Media*, 2016.

[54] Keith S. Taber, "The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education," *Research in Science Education* 48, no. 6 (December 1, 2018): 1273–96, https://doi.org/10.1007/s11165-016-9602-2.

[55] Rostina Sundayana, "Statistika Penelitian Pendidikan," *Bandung: Alfabeta*, 2014.

the collected data showed that the data was consistent and normally distributed. Following these assessments, the effectiveness of the online SPL model was subsequently evaluated using a paired t-test. The results of these calculations are presented in Table 7.

Table 7
Paired T-Test Results

t count	Sig. (p)	Description
3.930	0.002	The difference between the pretest and the posttest is sizable.

Source: Personal Document

The paired t-test, as calculated in Table 7, resulted in a t-count of 19.078 and a significance value of 0.002. This shows that the obtained significance value (0.002) was less than the threshold of 0.05. Consequently, it was concluded that the utilization of the online-based SPL model has led to a significant improvement in the collaborative skills of the observed students. In the study, the level of consistency in the learning effects among the three classes was examined using a one-way analysis of variance test. Table 8 presents an overview of the ANOVA results.

Table 8
Summary Of One-Way Anova Test Results

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.037	2	.019	.364	.696
Within Groups	3.662	72	.051		
Total	3.699	74			

Source: Personal Document

As indicated in Table 8 above, the presented data showed an F-count of 0.364 with a significance value of 0.693. Comparing this F-count (0.364) with the F-table value (3.12) and considering the significance value (0.693) exceeding 0.05, it can be concluded that the learning outcomes obtained using the online-based SPL model were consistent across all three grade levels.

RESULT AND DISCUSSION

The 4Cs, specifically collaborative skills, are a vital component in the 21st century.[56,57] Based on this understanding, it becomes important that collaboration be fostered among students from an early age as this skill will enable the students to effectively and critically tackle daily challenges and achieve their fullest potential.[58,59] Collaborative skills are a crucial element in the development of future citizens. These attributes equip students with the ability to ask significant questions about various phenomena, generate ideas, gather and assess relevant information, handle abstract concepts, maintain an open-minded approach, and effectively communicate and collaborate with their peers.[60,61,62,63] According to Naila[64] collaborative skills include active participation in group discussions (contribution aspect), encouraging peers to share their opinions and ideas (effectively working with diverse members), distributing tasks to attain learning objectives (contribution aspect), and providing ideas for problem-solving (problem-solving aspects).

As rightly observed in previous studies, the prevailing situation in schools emphasizes the fact that the collaborative skills possessed by students remain at a low level. This is supported by a survey conducted by TIMSS (Trends in International

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[56] Bhati and Song, "New Methods for Collaborative Experiential Learning to Provide Personalised Formative Assessment."

[57] Ilse Ruys, Hilde Van Keer, and Antonia Aelterman, "Examining Pre-Service Teacher Competence in Lesson Planning Pertaining to Collaborative Learning," *Journal of Curriculum Studies* 44, no. 3 (June 1, 2012): 349–79, https://doi.org/10.1080/00220272.2012.675355.

[58] Adilah Afikah et al., "Student's Higher-Order Thinking Skills and Collaboration Skills in Online Learning during Pandemic," *Int J Eval & Res Educ* 12, no. 1 (2023): 23–33, https://doi.org/10.11591/ijere.v12i1.23797.

[59] Spyridon Doukakis and Evita C. Alexopoulos, "Online Learning, Educational Neuroscience and Knowledge Transformation Opportunities for Secondary Education Students," *Journal of Higher Education Theory and Practice* 21, no. 3 (June 2, 2021), https://doi.org/10.33423/jhetp.v21i3.4141.

[60] Cai-Ting Wen et al., "Students' Guided Inquiry with Simulation and Its Relation to School Science Achievement and Scientific Literacy," *Computers & Education* 149 (May 1, 2020): 103830, https://doi.org/10.1016/j.compedu.2020.103830.

[61] Marcel Bassachs et al., "Fostering Critical Reflection in Primary Education through STEAM Approaches," *Education Sciences* 10, no. 12 (December 2020): 384, https://doi.org/10.3390/educsci10120384.

[62] Filiz Kalelioğlu and Yasemin Gülbahar, "The Effect of Instructional Techniques on Critical Thinking and Critical Thinking Dispositions in Online Discussion," *Journal of Educational Technology & Society* 17, no. 1 (2014): 248–58.

[63] Tamene Atsebiha Tegegne and Asrat Dagnew Kelkay, "Comparative Study of Using 5E Learning Cycle and the Traditional Teaching Method in Chemistry to Improve Student Understanding of Water Concept: The Case of Primary School," *Cogent Education* 10, no. 1 (December 31, 2023): 2199634, https://doi.org/10.1080/2331186X.2023.2199634.

[64] Naila, "The Effectiveness of Science Project Learning Based on Entrepreneurship Model to Improve Elementary Students' Collaborative Skills," 2020.

Mathematics and Science Study) in 2015, which placed Indonesia at the 44th position out of 49 countries,[65] indicating low achievement in this regard. Furthermore, in an observation conducted at an elementary school in Surabaya, Indonesia, it was shown that students were not assessed based on their collaborative skills. The results of this observation indicated that fifth-grade students had an average score of 66.4 on a scale of 0-100. This means that in terms of collaborative skills, this set of students was classified in the low category.

One of the potential solutions to address these issues is the implementation of the online-based SPL model. This model consists of six phases namely initiating with essential questions, project design, scheduling, monitoring, assessment, and evaluation. Accordingly, the SPL model places a significant emphasis on leveraging the existing knowledge of students as a foundation for further learning, making it particularly suitable for elementary school students.

The online-based SPL model was developed by merging two other practical models namely collaborative learning (CL) and project-based learning (PjBL). These models have been observed to have the capability to enhance the rate at which students comprehend, stimulate greater interest in learning through active participation, and improve collaborative skills.[66,67,68]

This study was carried out within a virtual learning environment, with the participation of 75 elementary school students from classes 5A, 5B, and 5C. The primary objective of this investigation was to enhance collaborative skills through the implementation of an online-based SPL model in science lessons.

The obtained results underscored the effectiveness of the online-based SPL model in the context of online learning. This was evidenced by the significant increase observed in the collaborative skills of the students, as indicated by the significant difference

[65] Schleicher, "PISA 2018: Insights and Interpretations."

[66] Razali Sharifah Nadiyah and Shahbodin Faaizah, "The Development of Online Project Based Collaborative Learning Using ADDIE Model," *Procedia - Social and Behavioral Sciences*, World Conference on Technology, Innovation and Entrepreneurship, 195 (July 3, 2015): 1803–12, https://doi.org/10.1016/j.sbspro.2015.06.392.

[67] Ha Le, Jeroen Janssen, and Theo Wubbels, "Collaborative Learning Practices: Teacher and Student Perceived Obstacles to Effective Student Collaboration," *Cambridge Journal of Education* 48, no. 1 (January 2, 2018): 103–22, https://doi.org/10.1080/0305764X.2016.1259389.

[68] Asma Ali Mosa Al-araibi, Mohd Naz'ri bin Mahrin, and Rasimah Che Mohd Yusoff, "Technological Aspect Factors of E-Learning Readiness in Higher Education Institutions: Delphi Technique," *Education and Information Technologies* 24, no. 1 (January 1, 2019): 567–90, https://doi.org/10.1007/s10639-018-9780-9.

between the pretest and posttest scores, meeting high criteria. Furthermore, the ANOVA test results for the n-gain scores of the participants showed high criteria, indicating that their collaborative skills were consistent and normally distributed across the entire class. Based on the results obtained from the evaluation and analysis, it was concluded that the online-based SPL model is suitable for cultivating collaborative skills among elementary school students in online learning settings.

Following evaluation and analysis, the efficacy and reliability results (refer to Table 2) regarding the content and configuration of the research tools showed that the scientific learning resources were highly effective and dependable. This indicated that the resources utilized were considered valuable as learning aids. In accordance with this, the collaborative skills of the observed students were assessed through a test instrument consisting of 10 short-answer questions based on the collaborative skills index.

From the research data, it was observed that the online-based SPL model effectively enhanced collaborative skills, with each examined class experiencing an increase in their average value. This was substantiated by the n-gain scores, which showed an increase of 0.56 (56%) for class A, 0.59 (59%) for class B, and 0.61 (61%) for class C (see Table 3). It is important to state that these values remained the same for all three experimental classes. Additionally, the paired t-test, which was conducted using both uniform and normally distributed data, showed a significant difference. The results of this test comprised an F-count of 0.364 with a significance value of 0.696, greater than the minimum threshold of 0.05 (refer to Table 7). Based on these findings, it was concluded that the utilization of the online-based SPL model for learning did not vary significantly and remained consistent across the three classes.

CONCLUSION

In conclusion, based on the results of this study, it was established that the application of an online-based SPL model effectively enhanced the collaborative skills of elementary school students. This effectiveness was achieved through the stages of online-based SPL, which include posing essential questions, project planning, progress monitoring, results evaluation, and experiences assessment. Accordingly, the effectiveness of the utilized learning model was observed to be particularly prominent

during project planning, particularly in terms of seeking determination strategies and evaluating solutions for further learning.

Based of these conclusions, it was recommended that the use of online-based SPL models becomes a fundamental component for educational institutions engaged in remote learning studies. However, it is important to understand that this approach was particularly focused on enhancing the collaborative abilities of primary students and improving science learning outcomes.

Online-based science project learning, as an alternative instructional model, holds great promise for enhancing the collaborative skills of students by drawing inspiration from Project-based learning (PBL), an educational approach that empowers students to tackle real-world issues and challenges. This comprehensive approach has been found to effectively improve the critical thinking, problem-solving, collaboration, and communication abilities of students.

In this study, several recommendations were made for future research. These include the fact that further studies could engage in Investigating the effectiveness of various types of online-based science projects in enhancing the collaborative skills of students; Exploring the impact of online-based science project learning on their motivation and engagement; Comparing the effectiveness of online-based science project learning to traditional classroom instruction in terms of the collaborative skills of students; Examining the role of teacher support and guidance in online-based science project learning and how it influences collaboration; Investigating the long-term retention of material and transfer of skills to different contexts among students who have experienced online-based science project learning.

In summary, online-based science project learning, as an alternative instructional model, has the potential to enhance the collaborative skills and engagement of students in science education. In this regard, further studies can play a crucial role in refining and optimizing this approach to fully harness its advantages for students.

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The authors declare no conflict of interest.

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