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COMMENTARY

How to Develop 21st Century Skills in Students: The Role of LEGO® Education

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"Every skill you acquire doubles your odds of success." –Scott Adams

THE concept of "21st century skills" emerged in response to the challenges of the modern era. The Partnership for 21st Century Skills (P21) was a pioneering force in this movement and developed the Framework for 21st Century Learning in the early 2000s (Shi et al., 2016). In 2012, the U.S. National Research Council issued a report titled *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*, which marked a new direction for educational reform and development in the U.S. and provided valuable insights for nations worldwide. The report identified three domains of competence that comprise 21st century skills: cognitive, intrapersonal, and interpersonal. Each domain consists of several clusters of relevant competencies. The cognitive domain includes cognitive processes and strategies, knowledge, and creativity. The intrapersonal domain encompasses intellectual openness, work ethic/conscientiousness, and positive core self-evaluation. The interpersonal domain is divided into two clusters: teamwork and collaboration, and leadership (National Research Council, 2012). Developing these skills is not only crucial for personal growth and achievement, but also essential for the progress of society as a whole. Therefore, individuals and educational institutions should prioritize the cultivation of 21st century skills in today's rapidly evolving social and economic environment.

P21 has proposed comprehensive support systems to promote 21st century skills education and ensure student mastery of these skills. These support systems encompass several key elements, including 21st century standards, assessments, curriculum and instruction, teacher professional development, and learning environments. (i) 21st century standards focus on 21st century skills, content knowledge and expertise, building understanding across key subjects and interdisciplinary themes, and promoting deep understanding rather than superficial knowledge. They also emphasize the value of engaging students with real-world data, tools, and experts they will encounter in learning, in their future careers, and in their everyday lives. (ii) The evaluation system for 21st century skills supports a balance of assessments, including high-quality standardized testing, as well as effective formative and summative classroom assessments. The system emphasizes providing useful feedback on student performance that is integrated into everyday learning. It also requires a balance of technology-enhanced, formative, and summative assessments that measure student mastery of 21st century skills. In addition, the evaluation system enables the development of portfolios of student work that demonstrate mastery of 21st century skills to educators and prospective employers. This approach encourages the use of a balanced portfolio of measures to assess the effectiveness of the educational system in reaching high levels of student competency in 21st century skills. (iii) 21st century curriculum and instruction are intended to teach 21st century skills in a discrete manner within the context of key subjects and interdisciplinary themes. They also focus on providing opportunities for applying these skills across different areas and adopting a competency-based approach to learning. Innovative learning methods that integrate supportive technologies, inquiry- and problem-based approaches, and higher order thinking skills are enabled to promote effective learning. Additionally, the integration of community resources beyond school walls is encouraged to create a more holistic learning environment. (iv) Effective teacher professional development programs highlight ways in which teachers can integrate 21st century skills, tools, and teaching strategies into their classroom practice, while balancing direct instruction with project-oriented teaching methods. They also emphasize how a deeper understanding of subject matter can enhance problem-solving, critical thinking, and other 21st century skills. Professional development programs enable the creation of 21st century professional learning communities for teachers, where they can model the kinds of classroom learning that best promote 21st century skills for students. Furthermore, these programs cultivate teachers' ability to identify students' particular learning styles, intelligences, strengths, and weaknesses. (v) 21st century learning environments aim to create learning practices, human support, and physical environments that will facilitate the teaching and learning of 21st century skill outcomes. These environments support professional learning communities that enable educators to collaborate, share best practices, and integrate 21st century skills into classroom practice. They allow students to learn in relevant, real-world 21st century contexts and provide equitable access to quality learning tools, technologies, and resources. Moreover, they support expanded community and international involvement in learning, both face-to-face and online (Partnership for 21st Century Skills, 2019).

Lego is a classic line of toy products, originating from the Danish words LEG and GODT, meaning "playing well". While providing entertainment and fun, it also promotes the development of 21st century skills such as creativity, critical thinking, collaboration and communication in children. With 90 years of experience in toy manufacturing, game development, and game-assisted education, the LEGO® Group is a leader in this field. LEGO® toys and LEGO® education are its main business components, with the latter being established in 1980. Over the last 30 years, LEGO® Education has developed numerous sets of educational tools for children, adolescents, and adults across subjects like science, technology, mathematics, and sociology. The LEGO® Education product range can be used in both classroom teaching and extracurricular activities and skills training (Wang & Wang, 2017). Moreover, LEGO®'s Education Department has partnered with governmental organizations and world-famous educational institutions to promote and apply LEGO® education in basic education across various countries like China, the United States, France, Peru, Russia, Brazil, and South Africa (Liu, 2016).

The Effect on Gifted Students' 21st-Century Skills of Supporting Science Teaching with LEGO® Education® BricQ Motion Essential and Student Opinions on this Instruction in this issue was a study that investigated the impact of the Lego Education BrickQ Motion Essential Set on the 21st century skills of gifted students in the teaching of Force and Motion. It used a mixed research design that incorporated both quantitative and qualitative analysis. The research findings showed that the Lego Education training program was effective in enhancing the 21st century skills of gifted students and also received positive feedback from them. Therefore, this study recommended that Lego Education should be applied in the training of gifted students at different grade levels (Babaoğlu & Güven Yıldırım, 2023).

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COMMENTARY

A Learner-Centered Teaching Model

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"Education is not the filling of a pot but the lighting of a fire." –W.B. Yeats

A TEACHING model is a plan or pattern that can be used to shape curriculum, to design teaching materials, and to guide instruction in the classroom and other settings. It is often developed based on specific educational philosophies and teaching theories, providing stable structures and procedures for teaching activities. Teaching models can be illustrations of instructional theories or generalizations of teaching experiences, allowing educational researchers to apply their ideas and concepts to practice, and practitioners to generalize about their instructional experiments and experience (Joyce & Weil, 1996). With the help of teaching models, educators can optimize their teaching methods and promote better learning outcomes for their students.

In the 1970s, Bruce Joyce, an American scholar published Models of Teaching after extensive research. Over the years, the book has been revised and expanded, providing deeper insights into teaching model research and including a greater variety of instructional models. It has become a classic in pedagogical research and the entire educational field worldwide. In this book, teaching models are categorized into four families: the social family, information-processing family, personal family, and behavioral systems family. Each family includes a number of teaching models (Joyce et al., 2009). Initially, Joyce and his colleagues evaluated teaching models from the perspective of "teaching." However, as their explorations deepened, they shifted their perspective to "learning." They concluded that teaching models are really learning models, which marked a significant shift in the trend of theoretical research and practice in teaching models.

Since the 1980s, foreign research on teaching paradigms has been introduced to China and gained significant interest from the Chinese educational community. Based on the experiments with these paradigms in its primary and secondary schools, Chinese basic education has generated a series of teaching models of its own characteristics, including teacher-guided self-education, six-step module teaching, experiential learning, and structured module teaching. Subsequently, Chinese educational academia has conducted more theoretical research into teaching models, resulting in the production of relevant theories such as the theory of behavioral paradigms, methodological systems, categorical structure, system elements, and procedural methods (Jin, 2018). As a result, practical explorations of teaching paradigms have been strengthened by in-depth theoretical research. In recent decades, new teaching models have emerged with the assistance of educational technology. Nevertheless, existing teaching paradigms are still limited by being restricted to textbook contents and focusing on teaching rather than student learning. Despite being advocated for many years, the educational idea of "student-centered" instruction cannot be successfully implemented due to the lack of relevant teaching models.

Protocol-guided Teaching: An Experiment in Chinese Basic Education in this issue is a comprehensive review of the background, characteristics, and implementation strategies of the protocol-guided teaching model. This teaching model is derived from the instructional experience of Chinese educational practitioners. It places a strong emphasis on student learning as the primary focus. Under the protocol-guided teaching paradigm, the traditional teacher instructional plan is replaced by a student learning protocol. Course contents are reconstructed with meaningful questions, and students are encouraged to engage in active problem-solving rather than passive reception of knowledge. The classroom dynamic is shifted towards discussion and group study, rather than teachers' unilateral transmission of knowledge (Wang & Zhu, 2023). The learning protocol is the central component of the protocol-guided teaching model, and it can effectively facilitate the implementation of the "student-centered" educational concept. Teachers create the learning protocols in advance and use them to guide students in their pre-class preparation, classroom activities, and post-class knowledge application. This approach represents a significant departure from traditional instructional methods in terms of teaching organization and procedure. We hope that this teaching model, which places learners at the center of the educational process, will benefit more students in the future.

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ORIGINAL ARTICLE

What Kind of Novice Teachers Would Prefer the Autonomy-Supportive Teaching Method? An Empirical Study Based on Large-Scale Research Data

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***Abstract**: Given that autonomy-supportive teaching has the potential to enhance students' learning motivation and promote their self-development, it is of immense value and far-reaching significance to assist novice teachers in mastering and employing this teaching method effectively. The study employs multi-variable linear regression to analyze the factors influencing novice teachers' use of the autonomy-supportive teaching method and Shapley value decomposition to reveal the contribution rate of each variable. The analysis is based on data extracted from a large-scale survey of urban districts. The findings of the study are as below: (i) Scientific research literacy, professional knowledge, professional competence, and job satisfaction have a significant impact on novice teachers' adoption of the autonomy-supportive teaching method; (ii) the greatest impact is exerted by scientific research literacy, followed by professional competence and professional knowledge. Therefore, teacher professional development is the key to the successful implementation of autonomy-supportive teaching by novice teachers, while environmental support is the path. To accomplish this, it is necessary to improve their scientific research literacy and emphasize the application of their scientific research results; expand their professional knowledge and skills; increase the frequency of in-service training and create a positive development environment; encourage professional exchanges and eliminate utilitarian competition; and motivate teachers' pursuit of life meaning and attend to their emotional needs.*

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Keywords: *Novice Teacher, Autonomy-Supportive Teaching, Teacher Professional Development*

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Conflict of Interests*: None*

Research Proposal and Literature Review

STUDENTS' self-motivation in learning and capacity for their self-development have attracted a great deal of public attention as education and teaching reforms intensify. In the classroom, however, overly utilitarian, dubious teaching practices such as "cramming" and "teacher-centered instruction" are still prevalent. Consequently, education becomes an activity of indoctrination and spiritual segregation (Hu, 2010). Prior research has demonstrated a decline in learning motivation and a worsening learning experience among Chinese elementary and secondary school students as they progress through the grades (Yuan et al., 2015). In this context, it is asserted that autonomy-supportive teaching can meet students' fundamental psychological needs, encourage their learning motivation, alter their negative emotions, and thereby increase their academic inputs and enhance their academic outcomes (Wang & Zhao, 2022). "Autonomy-support" refers to the support for students' self-directed learning, which is a central concept underlying Deci's 1980s self-determination theory. Based on self-determination theory, some scholars have defined autonomy-supportive teaching as an instructional method in which teachers in the authoritative position are receptive to students' opinions, capable of perceiving their thoughts and understanding of subject matter and willing to provide them with information and options without acting coercively or mandatorily (Deci & Ryan, 1985). Regarding the operational definition of the autonomy-supportive teaching method, Assor et al.'s (2005) proposal has been well received in both China and other nations; it proposes dividing teachers' autonomy-supportive behaviors into three distinct dimensions, namely encouragement of student independent thought, establishment of meaning and connection, and support for interest development. In the present study, autonomy-supportive teaching is defined as a method of instruction that encourages students to think independently and inquire actively in order to facilitate their knowledge internalization, stimulate their learning motivation, and increase their self-development potential.

The teacher is one of the key players in the educational process, as demonstrated by earlier studies (Hattie, 2015). Compared to more seasoned educators, new teachers are at a unique and crucial point in their careers where they must overcome obstacles, problems, and uncertainties in order to pursue survival and improved development (Clark, 2012). The most common definition of a novice teacher is one who has not been in the classroom for more than three or five years. New teachers in this study are individuals with fewer than five years of classroom experience. Early training and development experiences for novice teachers often have a stronger impact on their entire teaching careers than later experiences do (Xie & Zou, 2015). Investigations into the variables that influence rookie teachers' adoption of autonomy-supportive teaching may yield more useful and constructive suggestions and recommendations for motivating and assisting novice teachers to master this teaching strategy.

Research on the precise elements affecting novice teachers' use of the autonomy-supportive teaching style hasn't been studied much up to this point. However, several studies have looked more broadly at the variables influencing teachers' use of autonomy-supportive teaching. These influencing elements can be loosely separated into two categories: those relating to the external environment and those that are personal to the teachers themselves. On the basis of the common-sense paradigm (Marsh, 1996), which emphasizes the positive correlations between the two (e.g., scientific research can inspire the invention of teaching methods; Neumann, 1992), several researchers have explored the relationships between teaching and scientific research in the former case. In eight colleges and universities in the United Kingdom, Kent conducted a study of the professors and students in four majors. The results showed that research has a good impact on teaching and vice versa (Kent, 2001). Research findings revealed the positive correlations between teachers' subject-matter expertise and teaching methodology expertise and their educational quality (Chen, 2019), and the prevalence of cognitive psychology has also inspired scholars to consider the potential impact of teachers' internal cognitive processes on their educational behaviors (Lin, 2007). Additionally, the behavioral theory claims that an individual's competence can be represented in their particular behaviors when carrying out professional responsibilities (Liu, 2018), which can account for the influence of a teacher's professional competence on their teaching behaviors. The field theory suggests that some fields have an impact on everyone's behavior in terms of the external environment. In their industries, beginning teachers are frequently exposed to issues with administration, coworkers, workload pressure, and other external variables. In He's (2007) investigation into the connections between teaching approach and job satisfaction, indicators for job satisfaction included workload, interpersonal relationships, and satisfaction with school leadership. The study's findings showed that teachers with higher levels of job satisfaction tended to use creative, critical, radical, and integral teaching strategies. We identify scientific research literacy, professional knowledge, and professional competence as personal factors and work satisfaction as an external factor in the adoption of the autonomy-supportive teaching approach by novice teachers based on the aforementioned theories and literature study.

Currently, the majority of quantitative research on autonomy-supportive teaching focuses on its effect on students' learning motivations, while lesser studies examine the factors that influence teachers' adoption of the method from the teacher's perspective. In addition, the majority of researchers have only examined the factors influencing teachers' use of the autonomy-supportive teaching method in a single dimension, such as the dimension of teaching efficacy, whereas few have examined the factors from a multidimensional perspective that includes scientific research literacy, professional knowledge, and professional competence. In addition, numerous studies have included teachers with varying lengths of experience in their samples, while few have focused on novice educators. The current study utilized data from a large-scale survey in urban districts of X City and employed the multi-variable linear regression model to evaluate the influences of novice teachers' demographic characteristics, scientific research literacy, professional knowledge, professional competence, and job satisfaction on their adoption of the autonomy-supportive teaching method; it also determined the contribution rate (weight) of each factor via Shapley value decomposition.

Research Design

This study investigated the influencing factors in novice teachers' adoption of the autonomy-supportive teaching method from three perspectives, namely, the demographic characteristics of novice teachers, personal factors, and environmental factors, in order to reveal the basic features of novice teachers who are pro to the autonomy-supportive teaching method and to make improvement suggestions for their teaching techniques.

Research Subjects

The participants of this study are novice teachers serving in kindergartens and primary and secondary schools in X City who were randomly selected to take part in the questionnaire survey on novice teachers' career development administered by the Education Bureau of X City. After screening the retrieved questionnaires, a total of 2,290 subjects with valid data were eventually obtained.

Research Tools

The questionnaires used in the survey were self-created or adapted versions of existing ones, with substantial reliance on the OECD's teacher questionnaire to determine the substance of novice teachers' professional development. The poll also includes a section on basic information for teachers and other associated metrics.

In this study, the dependent variable is the autonomy-supportive teaching method. We developed the Autonomy-Supportive Teaching Method Questionnaire in accordance with the classification of teachers' autonomy-supportive behaviors from Assor et al. (2005): encouragement of student independent thought, establishment of meaning and connection, and support for interest development. From relevant investigations by Liang et al. (2020), Zeng and Huang (2014), Niu (2021), and Lai (2020), ten questions were extracted. Cronbach's alpha coefficients for the questionnaire and the three factors are 0.876, 0.772, 0.809, and 0.839, while the composite reliability of the three dimensions is 0.839, 0.820, and 0.851, all of which are greater than 0.82 and therefore satisfy the criterion. The intra-group convergent validity is 0.566, 0.604, and 0.657, which are all greater than 0.56 and therefore satisfy the criterion. Each dimension has a CFI greater than 0.90 and an RMSEA less than 0.08, indicating that the model's goodness of fit is relatively high.

The explanatory variables include the demographic characteristics of novice teachers, their scientific research literacy, their professional knowledge, their professional competence, and their job satisfaction. Novice teacher demographic characteristics include their gender and in-service training. The four sub-dimensions of scientific research literacy are scientific research knowledge, scientific research practice and innovation, scientific research character, and scientific research attitude. The model meets the criteria with a Cronbach's alpha of 0.74 and a composite reliability of 0.66. We divided teacher professional knowledge into four sub-dimensions based on the Professional Standards for Secondary School Teachers (2012) and pertinent queries from Zhang's (2018) study: educational knowledge, disciplinary knowledge, teaching methodology knowledge, and general knowledge. This variable meets the criteria with a Cronbach's alpha of 0.89, composite reliability of 0.900, and intra-group convergent validity of 0.563. In addition to consulting the Professional Standards for Secondary School Teachers 2012, we extracted pertinent question items from the Niu (2021), Zhang (2018), Zhu (2020), and Jia (2020) studies when measuring teacher professional competence. The six sub-dimensions of teacher professional competence are: teaching design, teaching implementation, class administration, teaching evaluation, communication and cooperation, and reflection and improvement. The aggregate Cronbach's alpha coefficient is 0.900, the composite reliability is 0.902, and the intra-group convergent validity is 0.481, so the criteria are met. Teacher job satisfaction is comprised of satisfaction from school leadership and management, the professional development environment, salaries and perks, self-actualization, and work relationships, and their Cronbach's alpha coefficients are all greater than 0.8 and meet the criteria; the intra-group convergent validity of each sub-dimension is 0.843, 0.762, 0.655, and 0.604 and resembles the criteria.

The contents of the questionnaires were subjected to a common method bias check and Harman's single factor test, and the findings revealed that the variance explained by the first common factor is 38.46%, which is less than the crucial value of 40%. As a result, this study had no major common method biases.

Analysis Methods

OLS Multi-variable Regression Model

To assess the impact of each component on novice teachers' adoption of the autonomy-supportive teaching style, OLS multiple regression was used. The estimate is made using the ordinary least square regression model (OLS), as the dependent variable of the autonomy-supportive teaching style is a continuous variable. The following is established as the fundamental estimation model for this study:

$$Y_i = \beta_0 + \beta_{1demograph} + \beta_{2individual} + \beta_{3environment} + \varepsilon_i$$

Y_i denotes the autonomy-supportive teaching method, $\beta_{1demography}$ represents the demographical characteristics of the novice teachers, $\beta_{2individual}$ signifies personal factors in the novice teacher's adoption of autonomy-supportive teaching, $\beta_{3environment}$ indicates environmental factors, and ε_i and β_0 represent random disturbance and intercept, respectively.

Shapley Value Decomposition

Shapley value decomposition was administered to evaluate the weight of each variable that significantly influences the novice teacher's adoption of the autonomy-supportive teaching method, as the ordinary least squares method is unable to decompose the contribution of the influencing factors.

Results and Discussion

Research Results

Statistical Descriptions of Variables

According to the statistical descriptions of variables (**Table 1**), the majority of novice teachers are female. The average value of the variable of in-service training is comparatively low, indicating that most novice teachers receive infrequent training and have limited opportunities for professional development. Refer to **Table 1** for a description of the basic features of each variable.

Table 1. Statistical Descriptions of Variables (N=2290).

Variables		Variable Types	Minimum	Maximum	Mean	SD
Dependent Variable	Autonomy-Supportive Teaching Methods	Continuous Variable	2.13	5	4.28	0.56
Demographic Characteristics	Gender	Categorical Variable	1	2	1.83	0.38
	In-Service Training	Continuous Variable	1	4	2.38	0.98
Personal Factors	Scientific Research Literacy	Continuous Variable	1.67	5	4.27	0.62
	Professional Knowledge	Continuous Variable	1.43	5	4.36	0.55
	Professional Competence	Continuous Variable	2.60	5	4.30	0.51
Environmental Factors	Job Satisfaction	Continuous Variables	1.35	5	4.29	0.57

Table 2. Multivariate Linear Regression Results (Dependent Variable: the Autonomy-Supportive Teaching Method).

Variables		Model 1	Model 2	Model 3
Demographic Characteristics	Gender	-0.014 (0.031)	0.001 (0.016)	0.001 (0.016)
	In-Service Training	0.183*** (0.012)	0.008 (0.007)	0.008 (0.006)
Personal Factors	Scientific Research Literacy		0.451*** (0.015)	0.440*** (0.015)
	Professional Knowledge		0.119*** (0.017)	0.117*** (0.017)
	Professional Competence		0.370*** (0.020)	0.352*** (0.021)
Environmental Factors	Job Satisfaction			0.059*** (0.012)
Intercept		4.064	0.198	0.092
Sample Size		2290	2290	2290
R^2		0.034	0.724	0.727
Adjusted R^2		0.033	0.723	0.726
F		40.084***	1197.851***	1011.099***

*Notes: (1) The table shows standardized coefficients; (2) Bracketed contents are standard errors; (3) *p < 0.05; **p < 0.01; and ***p < 0.001.*

Results of Regression Analysis of Factors Influencing Teachers' Adoption of the Autonomy-Supportive Teaching Method

To build and evaluate the model, this study used the multivariate linear regression approach with SPSS 26.0. Stratified regression was utilized to include variables such as novice teachers' demographic traits, personal aspects, and environmental factors. The model test results indicate an R2 of 0.727 and a modified R2 of 0.726, showing a moderately good explanatory value; the model's regression findings are statistically significant. The collinearity diagnostics (VIF value) suggest that the regression equation has no severe collinearity, and the scatter plot shows that the regression equation has no heteroscedasticity. Refer to **Table 2** for more detailed regression analysis results.

Discussion

Demographic Characteristics of Novice Teachers

The regression results demonstrate that there is no significant gender difference in novice teachers' adoption of the autonomy-supportive teaching approach, which coincides with Liang et al.'s (2020) research findings but contradicts those of Ma et al. (2018). According to Ma et al., there is a gender difference in teachers' preferences for autonomy-supportive teaching methods: male teachers are more inclined to follow the control orientation and take actions in accordance with external and their own requirements, and thus are more likely to develop the motive of control; on the other hand, their female counterparts prefer the autonomous orientation and tend to take actions in accordance with their hearts or intentions, and thus are more likely to develop the motive of autonomy. According to other research, female professors prefer to use a structured teaching method, whereas male teachers typically encourage students to innovate and ask creative and difficult questions (Xu & Fu, 2005). Gender disparities in teaching methods have long been a contentious and inconclusive subject. Due to the limited proportion of male teachers in the sample, we concur that the variable of gender does not approach statistical significance in this study.

The in-service training variable's regression coefficient demonstrates a statistically significant positive effect, demonstrating how in-service training improves new teachers' abilities to instruct in a way that supports autonomy. In their study, Tessier et al. (2010) found that education on the benefits of autonomy support and training on autonomy-supportive teaching can improve teachers' autonomy-supportive behaviors. Relevant intervention research also found that teachers who have received training on autonomy-supportive teaching perform better when using this method (Decharms, 1976; Williams & Deci, 1996). Therefore, new teachers may effectively learn and apply the autonomy-supportive teaching approach through in-service training, which is consistent with the results of the current study. It is noteworthy that the in-service training possibilities available to the rookie teachers sampled for this inquiry are minimal and that in-service training occurs only occasionally. Thus, a key technique for motivating new teachers to use the autonomy-supportive teaching method should be to increase the frequency of training events and provide more opportunities for professional development.

Personal Factors

The implementation of autonomy-supportive teaching by novice teachers is significantly influenced by scientific research literacy, professional knowledge, and professional competence. This influence is statistically significant at a level of 0.01. The net explanatory value of personal factors was determined to be 69% by subtracting the value of R2 in model 1 from that in model 2. This value is significantly higher than that of demographic characteristics and environmental factors, suggesting that personal factors play a crucial role in promoting autonomy-supportive teaching and transforming teaching methods.

According to the standardized coefficients of personal factors shown in **Table 2**, the coefficient of teacher scientific research literacy has the highest value, indicating that the higher teachers' scientific research literacy, the more likely teachers are to use the autonomy-supportive teaching method, which is consistent with the findings of Gu et al.'s (2007) study. They discovered that teachers who focus on scientific research do a better job of improving teaching results and inspiring students than those who focus on information delivery. In their study, Coate et al. (2001) discovered that research-oriented teachers convey disciplinary knowledge, but non-research-oriented teachers just teach students how to pass tests. We believe that the overwhelming effect of teacher scientific research literacy stems from the fact that scientific research activities are, at their core, exploratory behaviors and that novice teachers with high scientific research literacy are more innovative, open, and inquisitive, making them more likely to encourage students to learn, think, and explore independently. The extremely high R2 value in this study suggests the presence of an endogenous factor, implying that scientific research and instruction are mutually causative and symbiotic (Neumann, 1992). Previous research, such as Kent's (2001) study on teachers and students in four majors from eight colleges and universities in the United Kingdom, has confirmed this. According to other studies, the promotional effect of scientific research on teaching is significantly stronger than that of teaching about scientific research (Zhang & Wu, 2009), emphasizing the necessity of good scientific research literacy for teachers.

A study has indicated that there exists a positive correlation between the level of professional competence of teachers and their inclination towards utilizing the autonomy-supportive teaching approach (Ma et al., 2018). Additionally, it has been found that teaching competence is significantly and positively associated with the teacher's adoption of "student-centered" teaching models (Yang & Xu, 2015). Novice teachers who possess enhanced professional proficiency tend to acquire advanced scientific knowledge in education and discipline and possess a more profound comprehension of the significance of "student-centered" autonomy-supportive pedagogy in fostering students' learning effectiveness and sustainable growth, in contrast to authoritarian teaching methodologies.

Environmental Factors

The findings from the stratified regression analysis presented in **Table** 2 indicate a statistically significant and positive association between job satisfaction and the use of autonomy-supportive teaching methods in novice teachers. This result is in line with He's (2007) research, which similarly found a positive and significant correlation between teachers' job satisfaction and their implementation of innovative and unconventional teaching approaches. This study investigated the impact of various factors, including teacher satisfaction with school leadership and management, the professional development environment, salaries and perks, work relationships, and self-actualization, on teachers' implementation of autonomy-supportive teaching. The findings, presented in **Table 3**, align with prior research. **Table 3** demonstrates that the adoption of autonomy-supportive teaching methods by teachers is significantly influenced by their satisfaction with self-actualization, work relationships, and professional development environments. As per Maslow's hierarchy of needs theory, the pinnacle of human needs is the requirement for self-actualization. Novice teachers who possess a strong desire for self-actualization and are committed to pursuing a career are more inclined to embrace the autonomy-supportive teaching approach. This is because of its efficacy in elevating students' motivation to learn and augmenting their academic proficiency, which, in turn, results in spiritual benefits for teachers and enhances their professional welfare. The study conducted by Roth et al. (2007) revealed a significant association between the sense of accomplishment experienced by educators and their inclination towards embracing the autonomy-supportive pedagogical approach. According to Ma et al. (2018), teachers are more likely to engage in autonomy-supportive teaching when they feel satisfied with the extent to which their personal competence is utilized in the teaching process. Furthermore, as per Mayo's theory on interpersonal relationships, individuals are considered to be "social creatures" who strive to fulfill not only their materialistic requirements but also their social and psychological necessities, such as companionship and a feeling of inclusion (Liu, 2010). Establishing a harmonious relationship between teachers and students, as well as fostering a cooperative and supportive relationship among colleagues, can facilitate a sense of belonging for novice teachers in their teaching endeavors. This, in turn, can enhance their motivation to pri-

Table 3. Influences of the Working Environment on Novice Teachers' Adoption of the Autonomy-Supportive Teaching Method.

	Encouragement of Independent Thinking	Establishment of Meaning and Connection	Support for Interest Development	Total Scores for Autonomy-Support
Satisfaction from School Leadership and Management	0.050 (0.036)	0.036 (0.033)	0.057* (0.034)	0.052 (0.030)
Satisfaction from Professional Development Environment	0.039 (0.038)	0.067* (0.035)	0.094*** (0.036)	0.075** (0.032)
Satisfaction from Salaries and Perks	-0.074*** (0.025)	0.010 (0.023)	-0.058** (0.024)	-0.041 (0.021)
Satisfaction from Work Relationships	0.162*** (0.038)	0.121*** (0.035)	0.179*** (0.036)	0.169*** (0.032)
Satisfaction from Self-Actualization	0.255*** (0.036)	0.237*** (0.034)	0.210*** (0.035)	0.259*** (0.030)
Control Variables	Yes	Yes	Yes	Yes
Intercept	2.013	2.079	1.882	1.996
Sample Size	2290	2290	2290	2290
R^2	0.166	0.181	0.196	0.222
Adjusted R^2	0.165	0.180	0.195	0.221
F	75.050***	89.944***	92.995***	112.272***

*Notes: (1) The table presents standardized coefficients; (2) Bracketed contents are standard errors; (3) *$p < 0.05$; **$p < 0.01$; and ***$p < 0.001$.*

oritize students' needs and provide sustained support for their overall growth and development. Moreover, the noteworthy impact of contentment derived from the professional development milieu suggests that enhancements in professional development prospects and the heightened significance attributed to teacher professional development by educational administrators will encourage inexperienced educators to maximize their pedagogical abilities. As previously stated, educators who possess greater teaching competence may exhibit superior performance in the provision of autonomy-supportive instruction (Ma et al., 2018). The provision of superior resources and conducive working conditions for the professional growth of novice teachers can foster their adoption of autonomy-supportive pedagogy.

Contribution Rates of the Factors Influencing Novice Teachers' Adoption of the Autonomy-Supportive Teaching Method Based on Shapley Value Decomposition

The analysis incorporated Shapley value decomposition to effectively demonstrate the diverse significance of each variable. **Table 4** displays the rate of contribution for each individual factor.

The data presented in **Table 4** offers support for further analysis of the contribution rates of all variables. The findings indicate that novice

Table 4 Shapley Values for the Autonomy-supportive Teaching Method.

Explanatory Variables	Shapley Value	Percent
Gender	0.00011	0.02%
In-Service Training	0.00828	1.14%
Scientific Research Literacy	0.27230	37.48%
Professional Knowledge	0.14379	19.79%
Professional Competence	0.23938	32.95%
Job Satisfaction	0.06271	8.63%
Total	0.72657	100.00%

teachers' scientific research literacy and professional competence possess greater explanatory power, accounting for 37.48% and 32.95% of the variance, respectively, with professional knowledge following at 19.79%. In general, novice teachers' adoption of the autonomy-supportive teaching method is more significantly influenced by personal factors than environmental factors.

Conclusion and Suggestions

Research Findings

The study utilizes a multi-variable linear regression model and the Shapley value decomposition method to investigate the impact of demographic characteristics, personal factors, and environmental factors on the adoption of autonomy-supportive teaching methods by novice teachers, based on large-scale survey data. The results indicate that there is a positive correlation between the amount of in-service training provided to novice teachers and their level of support for promoting student autonomy in learning. The utilization of autonomy-supportive teaching methods by novice teachers is significantly and positively influenced by their scientific research literacy, professional knowledge, and professional competence. The present study suggests that novice teachers' implementation of autonomy-supportive teaching is most significantly influenced by their satisfaction with self-actualization, work relationships, and professional development environments, among all environmental factors. The variable of scientific research literacy has the highest contribution rate, followed by professional competence and professional knowledge.

Suggestions

Strengthening Novice Teacher Professional Development

- *Enhancing the Scientific Research Literacy of Novice Teachers and Highlighting the Application of Scientific Research Results*

During the initial stages of their teaching profession, it is crucial for novice teachers to cultivate favorable dispositions towards scientific research. Hence, it is imperative for educational institutions to establish an encouraging scientific research milieu that can stimulate the interest of novice teachers towards scientific research. According to Chen and Yu (2019), active participation in research projects could be the most efficient approach towards enhancing one's scientific research literacy in the initial few years. Simultaneously, it is imperative to enhance the incentive structure to ensure that scientific research prioritizes tackling pragmatic educational concerns rather than solely pursuing career advancements. Furthermore, it is crucial to not solely prioritize the dissemination of scholarly articles but also the implementation of scientific research findings in educational contexts.

- *Expanding Novice Teachers' Professional Knowledge and Improving Their Professional Competence*

Novice teachers have a great opportunity to improve their teaching techniques by acquiring cutting-edge and extensive professional knowledge. Professional knowledge expansion can be a lifelong journey that enhances one's career. Novice teachers have the exciting opportunity to learn advanced educational theories and explore literature on the autonomy-supportive teaching method at the beginning of their careers. It is great to know that novice teachers can learn practical knowledge and gain experience from successful anchor teachers who implement autonomy-supportive teaching. This can be achieved through senior-junior teacher pairings and lesson observations. With years of practice in autonomy-supportive teaching and continuous reflection on teaching experiences, their professional competence is sure to improve.

Consolidating Environmental Support

- *Increasing in-Service Training Opportunities and Creating Positive Professional Development Environments*

Increasing the frequency of in-service training sessions is a viable strategy for facilitating the acquisition of proficiency in the autonomy-supportive pedagogical approach among novice teachers. Consequently, educational institutions are expected to arrange targeted professional development opportunities focused on fostering autonomy-supportive teaching. The optimization of training in autonomy-supportive teaching can be achieved by following the four distinct steps of the experiential learning theory: concrete experience, reflective observation, abstract conceptualization, and active experimentation.

- *Encouraging Professional Exchanges among Novice Teachers and Eliminating Over-Utilitarian Competition*

The creation of a positive work relationship has been shown to have a positive impact on the motivation and emotional well-being of novice teachers. To this end, schools should prioritize the establishment of a positive cultural environment, the development of a collaborative learning community, and the facilitation of professional exchanges among novice teachers.

- *Motivating Teachers' Pursuit of Life Meaning and Paying Attention to Their Emotional Experiences*

It is imperative for educational institutions to remain vigilant against an excessive focus on efficiency. In lieu of the aforementioned, it is anticipated that individuals will prioritize the principles of humanism within the context of teacher-student emotional interactions, implement a democratic approach to management, reduce inflexible performance metrics, and eliminate superfluous bureaucracy. By means of educational reform implemented within schools, in-service training, and educational research, it is possible for schools to facilitate the development of novice teachers' self-efficacy and self-actualization in their teaching profession.

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ORIGINAL ARTICLE

The Effect on Gifted Students' 21st-Century Skills of Supporting Science Teaching with LEGO® Education® BricQ Motion Essential and Student Opinions on this Instruction

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***Abstract**: In many countries, individuals have started to gain 21st-century skills from an early age. In Turkey, the education of gifted students is supported with activities enriched in parallel with these skills in science and art centers. The LEGO® Education® BricQ Motion Essential Set reinforces achievements with hands-on activities in science subjects, while also improving 21st-century skills such as problem solving, critical thinking, creativity, and collaboration. At this point, this study aims to examine the effect of the LEGO® Education® BricQ Motion Essential Set on the 21st-century skills of gifted students in the teaching of the 'Force and Motion' unit and to determine the students' views on the teaching process. The study was carried out in a science and art center in Konya in the spring term of the 2021–2022 academic year. The sample of the study consisted of 21 gifted students studying in Support-2 programmes (4th grade). An explanatory sequential design was preferred in the study. In the quantitative data collection phase of the study, a one-group pre-test/post-test experimental design was used. Interviews were used for the qualitative data collection phase. The quantitative data of the research were analyzed with the SPSS 26 statistical package program. Qualitative data were categorized according to themes and codes in accordance with content analysis. The results of the research showed that the LEGO® Education® BricQ Motion Essential Set was effective for 21st-century learning and the renewal of the skills of the gifted students participating in the research and that the students developed positive opinions about this education set. It is recommended to use LEGO® training sets to develop the 21st-century skills of gifted students.*

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***Keywords:** 21st-Century Skills, Science Teaching, Force–Motion, LEGO®, Gifted Student*

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Introduction

THE development of science and technology also changes the characteristics that people should have. People need some skills in order not to fall behind their age. 21st-century skills are the qualities that must be found in the people who can be employed in different business lines. 21st-century skills consist of 3 basic and 13 sub-skills: (i) learning and innovation skills (creative thinking, critical thinking, problem solving, communication, collaboration), (ii) information, media, and technology skills (information literacy, information and communication technology literacy, media literacy), (iii) life and career skills (flexibility and adaptability, self-management, social skills, productivity, and accountability, leadership) (P21, 2020). Schools that prepare children for the future should also provide students with 21st-century skills in addition to the curriculum. Students should acquire skills such as adaptation, communication, social skills, and the ability to solve problems in order to compete in the modern economy (Bybee, 2010). According to the OECD Learning Framework 2030, education should aim at more than preparing young people for the world of work; it should equip them with the skills they need to become active, responsible, and well-equipped citizens (OECD, 2018). Quality education encourages creativity and knowledge; it provides the acquisition of basic skills of literacy and numeracy, as well as analytical, problem solving, and other high-level cognitive, interpersonal, and social skills.

The National Association for Gifted Children (NAGC) has set a new generation of science standards for gifted students. These standards recommend raising the learning levels of students and using teaching strategies appropriate to their skills, such as analytical thinking and problem solving, which have long been advocated in their education (NAGC, 2014). In this context, the activities applied in the science and art centers that gifted students attend should be designed in a way to develop 21st-century skills.

Although the concepts of 'giftedness' and 'highly talented' are both included in the literature and previous Ministry of National Education of Turkey (MoNET) resources, the term 'gifted' is preferred instead of 'highly talented' for these children. Gifted students are individuals who have been determined by subject experts to perform at a higher level than their peers in terms of general or special abilities (MoNET, 1991). Special gifted individuals are defined as people who perform at a higher level than their peers in intelligence, creativity, sports, art, leadership capacity, or special academic fields (MoNET, 2013). A gifted individual in the field of science is a person who can successfully deal with "high-level" problems at a very young age (Gilbert & Newberry, 2017). Gifted students in science get bored with the repetition of basic subjects, and they enjoy challenges and problem-solving activities (Taber, 2017). Most mentally gifted children are interested in science, and it is emphasised that these students' skills, such as critical thinking, creativity, problem solving, and analytical thinking, are at the forefront (Ercan, 2013). Since gifted students show higher performance than their peers, they receive the gains of the curriculum in their own schools earlier than the activities held in science and art centers. To make continuous progress in their areas of talent, these students need learning experiences that require complex, creative, and innovative thinking and specific problem applications. Therefore, the activities used for gifted students should be very rich in terms of analysis, evaluation, and creativity (Taber & Corrie, 2017). In this context, it is thought that LEGO® Education® sets can be effective in creating the learning environments that gifted students need.

LEGO® sets are more intelligible and miniature abstractions of reality; they create a common language for the physical representation of abstract ideas and practical thoughts (Shores, 2017). When LEGO® is mentioned, the first thing that comes to mind is the toy, but especially today, LEGO® is also used for educational purposes. The LEGO® programme parallels elementary science content. Students can recognise LEGO® machines and mechanisms and simple machines such as gears, pulleys, and wheels, and produce projects on energy, force, and motion by combining them with software, motors, and receivers. The communication and engineering skills of students who participate in subject-based interdisciplinary activities together begin to develop (Bender, 2018). LEGO® Education® increases student engagement with experiences that encourage children to learn through physical and digital creation. At the core of this approach are the 4Cs (communication, collaboration, critical thinking, creativity) of the 21st century (LEGO®, 2022a). According to the LEGO® Play Well Report (2018), parents state that their children who spend time with LEGO® develop different and important skills. 95% of the parents participating in the research stated that they contributed to the development of skills such as problem solving, 96% creativity, 96% cooperation, socialisation, and communication. Studies of secondary school science education with LEGO® Education® sets have investigated the effects of LEGO® applications on academic achievement (Boyraz, 2019; Cavas, Kesercioğlu, Holbrook, Rannikmae, Özdoğru, & Gökler, 2012; Kılınç, 2014; Marulcu & Barnett, 2013; Uğuz, 2019), metacognition (Atmatzido, Demetriadis, & Nika, 2018; Cruz, 2019; Gibbon, 2007; Mojica, 2010), scientific process skills (Cavas, Kesercioğlu, Holbrook, Rannikmae, Özdoğru, & Gökler, 2012, Çayır, 2010; Koç Şenol, 2012; Kurtuluş, 2019; Okkesim, 2014; Özdoğru, 2013), problem solving (Atmatzido, Demetriadis, & Nika, 2018; Uğuz, 2019; Varnado, 2005), scientific creativity (Cavas, Kesercioğlu, Holbrook, Rannikmae, Özdoğru, & Gökler, 2012; Kurtuluş, 2019), computational skills (Uğuz, 2019), and attitude, interest, and motivation (Gürevin, 2019; Hinton, 2017; Kurtuluş, 2019; Kuş, 2016; Okkesim, 2014; Özdoğru, 2013; Uğuz, 2019). While studies on physics are at the forefront of the researchers' interest (Kılınç, 2014; Kurtuluş, 2019; Kuş, 2016; Marulcu & Barnett, 2013; Özdoğru, 2013), there are also studies on chemistry (Boyraz, 2019; Okkesim, 2014), biology (Cuperman & Verner, 2019; Çakır, 2019) and STEM (Coxon, 2011; Hinton, 2017; Kurtuluş, 2019). It is noteworthy that the studies involving LEGO® MINDSTORMS®-supported applications, especially with gifted students at the primary education level, are extremely limited (Coxon, 2011; Gibbon, 2007; Jamali, 2020). When the relevant literature is reviewed, there is no study examining the effect of the LEGO® Education® BricQ Motion Essential Set on 21st-century skills. To fill this gap, this study focuses on the effect of the LEGO® Education® BricQ Motion Essential Set on the 21st-century skills of gifted students. This study aims to examine the effect of the LEGO® Education® BricQ Motion Essential Set on the 21st-century skills of gifted students in the teaching of the Force and Motion Unit and to get students' views on the teaching process carried out with this educational set.

Methods

Research Model

In this study, the research model called a mixed method, in which quantitative and qualitative research methods are used together, was chosen in order to obtain the data for the purpose of the research. An explanatory sequential design mixed method, one of the mixed methods experimental designs, was used in the research. In this design, it is interpreted as how findings obtained from quantitative data help to explain qualitative data (Creswell & Plano Clark, 2018). A single-group pre-test/post-test experimental design was used to collect the quantitative data of the study. In the single-group pre-test/post-test design, the researcher first makes a pre-test measurement for a single group, then applies the experimental procedure, and finally performs the post-test (Creswell, 2017). The qualitative data of the study were collected using semi-structured interview questions. Semi-structured interviews emerge as a technique frequently used in educational science research, as they provide both standardisation and flexibility to predetermined questions (Türnüklü, 2000).

Working Group

The study group of the research consists of 21 gifted students attending the Support-2 (4th grade) groups in a science and art center in Konya in the spring semester of the 2021–2022 academic year. Participants were selected according to the convenience sampling method. The convenient sampling method allows the researchers to select individuals who are easily accessible in the selection of the participants, and also saves time and effort (Miles & Huberman, 2019). After the implementation process, seven of the volunteer students were selected at random, and semi-structured interviews were conducted with these students.

Data Collection Tools

Two different measurement tools were used to collect the quantitative and qualitative data of this study.

Quantitative Data Collection Tool

Quantitative data for the research were collected with the 21st Century Learning and Renewal Skills Scale developed by Belet Boyacı and Atalay (2016) and consisting of 39 items. The scale, which is a triple Likert-type scale, has 20 items about creativity and innovation skills, 12 items about critical thinking and problem-solving skills, and 7 items about cooperation and communication skills. The Cronbach's alpha reliability coefficient of the scale was calculated as 0.95.

Qualitative Data Collection Tool

Semi-structured interview questions developed by the researchers were used to collect the qualitative data for the study. The interview questions prepared by the researchers were presented to three faculty members in the field of science education and measurement and evaluation, and the necessary arrangements were made in line with the suggestions. The interview questions in which the qualitative data of the research were collected are given below.

1. What topics and concepts did you learn in the science class you used in BricQ Motion?
2. How did you feel during the lessons where you did these experiments?
3. Would you like to use LEGO® in all units of science lessons?

Data Collection Process

The data collection process of this research continued for 13 class hours (8 weeks). The application steps followed in the application and data collection processes are given in **Table 1**.

In the first lesson hour, the students, who were determined as the application group, were given information about the course and the application process. Then, the 21st-century learning and renewal skill scale was applied as a pre-test. In the next lesson, the application process was started and Free Throw, Bobsled, Hockey Practice, Tightrope Walker, and Gravity Car Derby

Table 1. Application process

Application	Hour
Pre-test	1 hour
Free Throw	2 hours
Bobsled	2 hours
Hockey Practice	2 hours
Tightrope Walker	2 hours
Gravity Car Derby	2 hours
Post-test	1 hour
Interview	1 hour

activities were held with the students using the LEGO® Education® BricQ Motion Essential Training set. These activities aim for students to gain the following skills:

- Planning and conducting research on the causes and effects of push and pull forces
- Gaining an understanding of 'Force and Motion'
- Conducting research on the effects of balanced and unbalanced forces
- Investigating patterns in an object's movement, predicting its next move
- Generating designs with the aim of changing the speed or direction of an object by pushing or pulling
- Actively participating in various discussions throughout the process
- Developing collaborative speaking skills
- Asking and answering questions
- Data analysis
- Discovering how to present their ideas

The LEGO® Education® official website was used for the lesson plans of the activities used in the lessons (LEGO®, 2022b). The training standards for the activities used and the explanations of the content are listed below.

Hockey Practice (NGSS-P2-1; ISTE 7c; CCSS.ELA-LITERACY.SL.1.2): In this activity, students will explore how different push and pull forces help to take and block penalty shots with mini figures of a hockey player and a goalie. They will also determine how the rack and pinion mechanism they have created will work to convert a linear pulling force into rotational thrust.

Tightrope Walker (NGSS-P2-1, ISTE 7c, CCSS.ELA-LITERACY.SL.1.2): In this activity, students will discover the force of gravity to keep a rope and mini figure of a tightrope walker in balance and protect the center of gravity with the help of bricks so that it does not fall.

Free Throw (NGSS-PS2-2; ISTE 4c,7c; CCSS.ELA-LITERACY.SL.1): In this activity, students will model a basketball court where they can shoot three points at a time with the mini figure of a basketball player, making use of levers and gears for the perfect basket.

Bobsled (NGSS 3-PS2-2, ISTE 4c, 6a, 7c, CCSS.ELA-LITERACY.SL.3.1): In this activity, students will explore how gravity affects the movement of the sledge by changing the mass of the sledges on which the mini figures ride, leaving them off the inclined plane. Students will also understand the mass–volume difference by making predictions.

Gravity Car Derby (NGSS 3-PS2-1, ISTE 4c, CCSS.ELA-LITERACY.SL.3): In this activity, students will design a safe gravity-powered car. They will conduct research by collecting evidence of the effects of balanced and unbalanced forces on the motion of a car using an inclined plane.

Photographs of the application of LEGO® activities in the lesson using the lesson plans are given below (**Figure 1**).

After the implementation process of the research ended, the 21st-century learning and renewal skill scale was applied to the same group as a post-test. Then, taking into account the randomness among 21 students, 7 volunteer students were determined. Semi-structured interviews were conducted with these students, and the application process was concluded.

Analysis of Data

The SPSS 26 package program was used in the analysis of the quantitative data obtained from this research. The Shapiro–Wilk test was applied to investigate whether the data collected from the 21st-century learning and renewal skill scale showed normal distribution. The Wilcoxon Signed Ranks test was used to determine whether there was a difference between the measurements made before and after the application. Content analysis, one of the qualitative data analysis methods, was used in the analysis of the qualitative data obtained from the study. Qualitative data was transferred to the computer environment after obtaining the permission of the participants. For the data that was turned into a written document, a coding key was created by three experts (two expert science educators and one science teacher). The expressions containing the codes were grouped according to their similarities and differences and turned into themes. After the themes were obtained, tables were created that included the theme, code, and frequency of students using the codes. The reliability of the codes was determined by calculating the inter-coder agreement. This ratio was found to be 0.83, and it was decided that the codes were consistent (Miles & Huberman, 2019). Since the students' own words would be quoted verbatim in the findings, each student was given a code name: S1, S2, S3, etc.

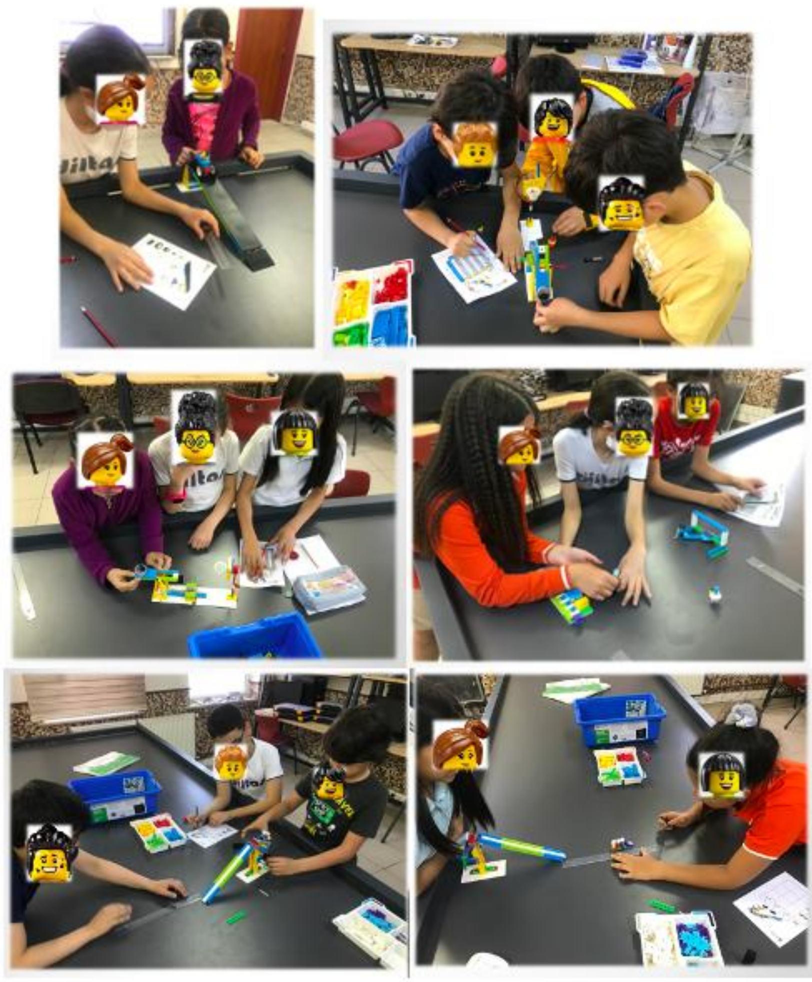

Figure 1. Images of the Application Process.

Findings and Interpretation

Findings related to the research were analyzed under two headings: quantitative findings and qualitative findings.

Quantitative Findings and Interpretation

The quantitative data of the research were obtained from the 21st-century learning and renewal skill scale applied to the students. Before proceeding to the analysis of quantitative data, it was investigated which statistical method would be used to analyze the data obtained from the relevant scale. In the analysis of data collected with the help of scales in quantitative research, parametric or non-parametric analyzes can be used according to the characteristics of the data set. To apply parametric tests in the analysis of the data, the entire data set must have a normal distribution. In this respect, the data obtained from the measurement tools should be analyzed with the appropriate normal distribution test, and it should be examined whether it provides the assumption of normality. According to the findings obtained, the use of parametric or non-parametric tests should be decided (Ghasemi & Zahediasl, 2012; Sim & Wright, 2002). In this study, normality analysis was performed on the data obtained from the scale used as a data collection tool, and the analysis method to be applied to the data set was selected according to the findings. The Shapiro–Wilk test was used to determine whether the data collected from the scale showed normal distribution. The Shapiro – Wilk test is used when $n < 50$ (Ghasemi & Zahediasl, 2012; Sawyer, 2009). The results of the analysis are given in **Table 2**.

Table 2 shows that when the students' 21st-century learning and renewal skills scale pre-test and post-test mean scores are examined, it is seen that the students' post-test mean scores are $p < 0.05$. This indicates that the data are not normally distributed. For this reason, it was decided to use non-parametric tests in the analysis of the data.

The Wilcoxon Signed Ranks test was used to reveal whether there is a difference between the pre-test and post-test mean scores of the 21st-century learning and renewal skills scale of gifted students who were taught science with the support of LEGO® BricQ Motion Essential. The analysis results are given in the table below (**Table 3**).

According to the results of the Wilcoxon Signed Ranks test in Table 3, there is a significant difference between the 21st-century skills scale total scores of the students participating in the research ($z = -2.420$, $p < 0.05$). The fact that the difference scores are in favour of negative ranks indicates that teaching has a significant effect on 21st-century skills.

Qualitative Findings and Interpretation

The qualitative data of this study were collected from seven students selected from the application group in order to explain the results obtained from the analysis of the quantitative data and illuminate the reasons for these results. Three semi-structured interview questions were asked of the students. The answers given by the students to the questions posed to them were reviewed in detail, and the codes and themes related to each question were extracted. As a result of the analysis of the codes and themes obtained, separate findings were obtained for each question, and direct quotations from the answers of the students were included in the findings. The answers given by the students to the first interview question are given in **Table 4**.

Table 2. Normality Distribution Of Gifted Students' 21st-Century Learning and Renewal Skills Total Scores.

		Shapiro–Wilk		
		Statistic	**df**	**p**
21st-century learning and regeneration skills	Pre-test total score	0.942	21	0.233
	Post-test total score	0.890	21	0.022*

**p < 0.05.*

Table 3. Wilcoxon Signed Rank Test Results of 21st-Century Learning and Renewal Skills Total Scores of Gifted Students.

Post-Test / Pre-Test	N	Rank Average	Rank Total	z	p
Negative Rank	4	11.50	46.00	-2.420	0.016*
Positive Sequence	17	10.88	185.00		
Ties	0				

**p < 0.05.*

Table 4. Theme, Code, and Frequency Values for the First Question.

Theme	Code	Frequency
Force and Motion	Frictional force	7
	Gravity	5
	Effects of force (acceleration, deceleration)	5
	Speed	4
	Balance	3
	Weight	1

According to **Table 4**, when the themes and codes that emerged regarding the answers given by the students to the first question are examined, it is seen that the answers belonging to the theme 'Force and Motion' emerged. When the codes of this theme were categorized, the students mentioned the codes of friction force (f = 6), gravity (f = 5), effects of force (f = 5), and speed (f = 4). In addition, some students' answers included the codes of balance (f = 3) and weight (f = 1). In general, it was determined that the students explained the experimental setups in detail while answering the questions. Direct quotations from the answers given by the students to the first question are presented below.

Table 5. Theme, Code, and Frequency Values for the Second Question.

Theme	Code	Frequency
Emotional states	Excitement	4
	Fun	3
	Happiness	3
	Curiosity	2
	Surprise	1
Learning states	Identifying concepts	1
	Observing concepts	1

Table 6. Theme, Code, and Frequency Values for the Third Question.

Theme	Code	Frequency
Positive evaluations	I would like to play in the lessons	7
	It's great to play with LEGO®	4
	A better understanding of science lessons	2
	I like to design LEGO®	1
	Science lessons are more fun	1
Criticism	I don't want to use LEGO® robots	1

S14: "We ensured that the weights were balanced on the rope while doing acrobatics. We made a ramp and learned the relationship between speed and weight. We learned the concepts of friction and gravity." (02.06.2022).

S20: "We learned about the forces used by the car, gravity, and friction. The less frictional force there is between the wheel and the ground, the faster the car goes." (02.06.2022).

The classification of the answers given by the students to the second interview question according to the themes and codes is shown in **Table 5**.

When the answers of the students to the second question were examined, the themes of 'emotional states' and 'learning states' were determined (**Table 5**). It was seen that the excitement (f = 4) code came to the fore the most in the 'emotional states' theme, which describes the feelings while experimenting with LEGO® training sets. In addition, codes such as fun (f = 3), happiness (f = 3), curiosity (f = 2), and surprise (f = 1) were also determined. The statements in which the students evaluated their own learning in their response were examined under the theme of 'learning situations'. In this theme, the codes for identifying concepts (f = 1) and observing concepts (f =

1) were determined. Direct quotations from the answers given by the students to the second question are presented below.

S14: "I am having fun. I am getting excited. Frankly, I am happy when I build LEGO®." (02.06.2022).
S1: "I am happy to learn something new, sometimes to be surprised when I understand the subject, to be happy." (02.06.2022).
S2: "I learned that I identified the concepts myself, I felt that I was observing them and getting to know the concepts closely." (02.06.2022).

The answers of the students to the third interview question are shown in **Table 6**.

According to **Table 6**, all of the students (f = 7) who answered the third question took part in the 'positive evaluations' theme. These students stated that they would very much like to use LEGO® in all units of the science course. Their comments are: very enjoyable (f = 4), a better understanding of science lessons (f = 2), enjoy designing things with LEGO® (f = 1), and science lessons are more fun (f = 1), indicated by codes. In addition, the answer of one of the students was evaluated under the theme of 'criticism'. This student mentioned that he was not willing to use LEGO® robots (f = 1). Direct quotations from the answers given by the students to the third question are presented below.

S14: "I would like to. Because by making LEGO®, science lessons are more fun and I understand better." (02.06.2022).
S15: "I would love to, but I would also like to use LEGO®'s robots." (02.06.2022).
S18: "Yes. Because playing with LEGO® is very nice. I like to design things out of LEGO® blocks." (02.06.2022).

Conclusion and Discussion

According to the quantitative findings after the research, it was observed that the 21st-century skills of the gifted students who were taught science with the support of LEGO® Education® BricQ Motion Essential in the 'Force and Motion' unit increased during the post-test. When the studies in which LEGO® training sets are used in the 'Force and Motion' unit are examined; Koç Şenol (2012) determined that the 7th-grade students participating in the study showed a significant difference in the science process skills of the students and their motivation for the science lesson with the LEGO® MINDSTORMS®-supported applications compared to the students in the control group. Kuş (2016) stated that LEGO® MINDSTORMS® 6th grade activities, which include the integration of science, technology, and design, are an effective approach for increasing students' academic success, attitude, and motivation. This study reveals that, unlike LEGO® educational robots, LEGO® Education® BricQ Motion Essential-supported science teaching is effective in the development of 21st-century skills of gifted students. In the literature, LEGO® training sets have been used in studies that examine sub-dimensions, although not directly on 21st-century skills. Cruz (2019), in his research with secondary school students, determined that LEGO® training sets have a significant effect on critical thinking skills, one of the 21st-century skills. Jamali (2020), in his study with 15 gifted female students, revealed that LEGO® robots had a positive effect on developing their creative thinking skills. Kurtuluş (2019) stated that the activities carried out with LEGO® improved students' scientific creativity and problem-solving skills. In the LEGO® Play Well Report (2018), parents stated that their children who spend time with LEGO® contribute to the development of skills such as problem solving, creativity, cooperation, and communication.

The LEGO® Education® BricQ Motion Essential Set can be used in STEM education due to its feature of bringing different disciplines together. Considering the studies on this subject, studies have found that the 21st-century skills of students who receive STEM education are improved (Bircan, 2019; Benek, 2019). In his research conducted with 34 primary school students, Bircan (2019) determined that the activities he prepared for STEM education had a significant effect on the students' attitudes towards STEM and 21st-century skills. In addition, he stated that the 21st-century skills such as communication, cooperation, creativity, and critical thinking of the 4th-grade students who participated in the research developed. Benek (2019) stated that STEM activities prepared on socio-scientific issues have positively affected the attitudes of 7th-grade students towards STEM and their 21st-century skills, and have improved them permanently. In his study, Açışlı Çelik (2022) concluded that the STEM activities he designed using the LEGO® Education® Spike Prime Set are beneficial in improving the problem-solving skills of 6th-grade students. The researcher also stated that these students approached the problems they faced in a solution-oriented manner with their critical thinking skills, and this situation positively affected their critical thinking skills. To explore the potential of the First LEGO® League (FLL) tournament to teach 21st-century skills, Ma and Williams (2013) examined the experience of a team participating in this league. They found that the tournament, in which LEGO educational robots were used, provided opportunities for team members to learn many 21st-century skills such as decision-making, problem solving, teamwork, flexibility, and self-management. It is predicted that gifted students will be able to develop their 21st-century skills and grow up to be useful individuals for their country if they are supported by an appropriate environment considering their qualifications (Şahin Çakır et al., 2021). Özcelik and Akgündüz (2018) found that STEM activities applied to gifted students improve 21st-century skills such as creativity, critical thinking, collaboration, and communication, and educational achievements in science and mathematics.

When the qualitative findings were examined as a result of the semi-structured interviews with the gifted students participating in the research, it was seen that they were able to express the concepts related to the 'Force and Motion' unit. Bender (2018) stated that students using LEGO® can recognise simple machines and produce projects on force and motion. When gifted students have control over what they will study, how they will study, and how they will show what they have learned, their motivation and desire increase (Kimball, 2001; Zimlich, 2012). The gifted students who participated in this research stated that they had fun while doing experiments with LEGO® and that they wanted to use LEGO® in other science units. Koç Şenol (2012) and Cameron (2005) found that their students developed positive opinions by reaching similar results in their studies using LEGO® sets. In addition, Kurtuluş (2019) stated that the activities implemented with LEGO® increased the motivation of students to learn science. In his study using LEGO® sets, Zengin (2016) revealed that his students were willing to use coding and robotic technology and developed a positive view toward computing. According to Silva (2008), the use of LEGO® sets in physics subjects enables students who have difficulty concentrating to improve their participation and motivation in the lesson.

While LEGO® was once just a toy for researchers and educators, today it is seen as an innovative way of teaching science and mathematics concepts with the development of technology (Kazez & Genç, 2016). Williams, Ma, Prejean, Ford, and Lai (2014) concluded that middle school students who participated in the summer camp where LEGO® robots were used improved their physics content knowledge. Students learn better by participating in experiments, role play, and building (Dodson, 2011). Children also develop their problem solving, creative, and critical thinking abilities to improve their engineering skills. (Kazez & Young, 2016). In addition to covering these features, being able to be used repeatedly and being durable are the reasons why LEGO® Education® BricQ Motion sets are preferred. The only downside to this set is that it is costly. Similarly, Bender (2018) interpreted the expense of LEGO® Education® products as a disadvantage.

When the findings obtained from quantitative and qualitative data are evaluated together, it can be seen that LEGO® Education® BricQ Motion Essential training sets contribute to the development of the 21st-century skills of gifted students, and they have positive opinions about these sets. For countries to have a place in the global economy, and for the success of children and society, it is vital to meet the needs of the 21st-century job market, and to inspire them by planning career goals at a young age (Ensign, 2017). LEGO® training sets help students make sense of career-oriented experiences and encourage their career awareness through an interdisciplinary approach (Holmquist, 2014). In this context, it is recommended to use LEGO® training sets to develop the 21st-century skills of gifted students. This research can be expanded by using LEGO® Education® sets for gifted students at different grade levels and students attending primary and secondary schools.

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ORIGINAL ARTICLE

Investigating the Effectiveness of Life Skills Training Guide on Pre-service Science Teachers' Development of Professional Knowledge Regarding Entrepreneurship Skills¶

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Abstract*: The present study aims to examine the effect of the life skills training guide on the development of pre-service science teachers' professional knowledge of entrepreneurial skills. The study included 82 pre-service science teachers studying in the third year of a public university in Turkey during the 2019-2020 academic year. The data of the study, which was conducted with a one-group pre-test-post-test experimental design, were collected using the entrepreneurship skills professional knowledge test. The data were analyzed using the professional knowledge assessment rubric and entrepreneurship skill indicators. The results of the study revealed that there was a significant difference between the pre-and post-test scores of the pre-service teachers in favor of the post-test scores. Following the experimental process, their professional knowledge about entrepreneurship increased. However, the number of pre-service teachers who were able to improve their professional knowledge scores to a high level was limited. Furthermore, following the experimental process, there was an increase in the number of pre-service teachers who were able to develop appropriate activities for students to gain entrepreneurial skills and to prepare tools for measuring and evaluating students' entrepreneurial skills in a way to include stressed indicators. Consequently, the present study provides science teacher educators with educational activities that they can model within the scope of teaching professional knowledge of entrepreneurship skills to pre-service science teachers.*

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Introduction

INCREASING the number of entrepreneurial individuals through training contributes to accelerating socioeconomic renewal and reducing poverty (Hoppe et al., 2017; Jones & Iredale, 2014). In globalizing economies, entrepreneurship is the key skill that motivates individuals to innovate and compete (Aldianto et al., 2018). Entrepreneurship is a life skill and has an essential place in the acquisition of other life skills (Birdthistle et al., 2023). For instance, entrepreneurial skill is a key element in the acquisition of skills such as teamwork (Amorim Neto et al., 2020), communication (Škare kare et al., 2022), analytical thinking (DeCoito & Briona, 2023), creative thinking (Durnali et al., 2023; Fillis & Rentschler, 2010) and decision making (Sanda & Sallama, 2023). Entrepreneurship is a skill that not only facilitates the teaching of life skills but also science process skills and engineering-design skills (Apaivatin et al., 2021; Bhakti et al., 2020; Deveci & Seikkula-Leino, 2023; Ribeiro et al., 2023; Saboorizadeh et al., 2023). It is very crucial for science education that such skills are integrated under the umbrella of entrepreneurship skills (Kirman-Bilgin, 2021). Therefore, entrepreneurship education has become a topic of worldwide interest in recent years. Entrepreneurship education aims to provide students with the necessary knowledge and skills to become entrepreneurs and to encourage them towards entrepreneurship (Badri & Hachicha, 2019). It is acknowledged that entrepreneurship education should be included in programs in all fields and levels of education (European Commission, 2012, 2013). Integrating entrepreneurship education with science courses is regarded as very crucial for the acquisition of this skill (Bolaji, 2012; Olokundun et al., 2014; Shahin et al., 2021). Effective teaching of such a skill in science courses is only achieved by teachers who have developed their professional knowledge in the field. Our teachers require model practices that demonstrate how to integrate traditional activities into their teaching process within the framework of innovations such as entrepreneurship skills (Van de Oudeweetering & Voogt, 2018).

Entrepreneurship education is a new learning domain for science teacher education (Achor & Wilfred-Bonse, 2013; Bacanak, 2013; Deveci & Seikkula-Leino, 2016). However, Seikkula-Leino et al. (2021) and Nwambam et al. (2018) revealed that the lack of activity in programs impedes effective entrepreneurship education. This indicates that teachers and preservice teachers require more guidance to promote the adoption and implementation of entrepreneurship education in science education. Stenholm et al. (2021) concluded that teachers who are unfamiliar with entrepreneurship are unable to create opportunities for their students, inspire them to be driven and motivate them to take action. Deveci and Çepni (2017) emphasized that science teachers can acquire professional knowledge of entrepreneurship through in-service training. Teachers must be taught effective and appropriate teaching methods during their pre-service years in order to raise students as entrepreneurial individuals (Seikkula-Leino et al., 2012). Lackeus (2015) underlines that learning activities that will ensure the development of entrepreneurial skills can be achieved through entrepreneurship-based assignments in which students themselves assume full responsibility. Avcı et al. (2022) discuss that differentiated educational activities can improve students' entrepreneurial skills. In order for science teachers to be able to utilize such ideas, they require professional knowledge of entrepreneurship. Köken and Çelik (2021) found that science teachers have awareness of teaching entrepreneurship skills, but they need training for practical teaching. The fact that entrepreneurship is a skill that can be acquired at an early age (Marques & Albuquerque, 2012) indicates the necessity of training teachers with professional knowledge and competence in entrepreneurship skills. On the other hand, there is also a need for model activities that include professional knowledge on how to teach entrepreneurship skills in science courses (İnaltekin et al., 2019; Kirman-Bilgin, 2019; Bal-İncebacak, 2022). The present study aims to contribute specifically to the science education literature in order to improve pre-service science teachers' professional knowledge of entrepreneurial skills in line with the same purpose. Accordingly, the following research question (*RQ*) was addressed:

> *RQ: What is the effect of the Life Skills Training Guide (LSTG) on the improvement of pre-service science teachers' professional knowledge of entrepreneurship skills?*

Literature Review

Entrepreneurship Skill in Science Education

Entrepreneurship is a dynamic and lengthy process that entails undertaking the activities of acquiring resources and seizing opportunities (Wei et al., 2019). Entrepreneurship skill has an essential role in developing skills such as problem-solving and taking responsibility (Partnership for 21st Century Skills, 2008; Gautam & Singh, 2015; Joensuu-Salo et al., 2020; Elo & Kurten, 2020; Fejes et al., 2019; Hoppe, 2016). Individuals with this skill have characteristics such as risk-taking, effective marketing, time management, a positive attitude towards change, and the ability to formulate the right strategy to reach the goal (Olokundun et al., 2014; Shane & Venkataraman, 2001; Lambing & Kuehl, 2000; Wickham, 2006; Fisher, Graham & Compeau, 2008). One of the most suitable fields to comprehend the characteristics of such a skill is science (McKinney, 2013). Acquiring entrepreneurial skills prepares individuals for the future and science education activities to serve for this purpose (Mbanefo & Eboka, 2017; Onwuachu & Okoye, 2012). The current education system in schools of Türkiye is based on an exam-oriented approach (Çetin & Ünsal, 2019; Mustafa & Buldur, 2021). However, this prevents individuals from being equipped with life skills such as entrepreneurship, which are needed in today's societies (Hoppe et al., 2017). The science education process aims to provide students with innovative skills such as non-traditional entrepreneurship (Pounder, 2016). The prominence of STEM (Science, Technology, Engineering, Mathematics) education in meeting the innovative skills deficit in the future has enabled STEM to be regarded as a tool for comprehending entrepreneurship skills (Eltanahy et al., 2020; Ezeudu et al., 2013; Kelley et al., 2020; Sarı et al., 2022; Winkler et al., 2015). Another prominent subject is the development of students' entrepreneurial skills in agriculture and husbandry in science courses and enabling them to make career plans for being an entrepreneur (Purwanto & Supriadi, 2019). Such activities are carried out to economically empower disadvantaged populations, especially in rural areas (Oluremi & Gbenga, 2011). When the literature on entrepreneurship education in science education is examined, it is observed that there are studies on professional entrepreneurship knowledge of teachers and candidates in very few European countries, especially in Finland (Deveci & Seikkula-Leino, 2016; Seikkula-Leino et al., 2012; Seikkula-Leino et al., 2010; Seikkula-Leino et al., 2021; Seikkula-Leino et al., 2015). These studies stress the need for professional development that enables teachers to associate entrepreneurship with science subjects. In Africa, especially in Nigeria, professional development practices on agriculture-based entrepreneurship education for pre-service science teachers have been implemented (Abdulmumini et al., 2020; Achor & Wilfred-Bonse, 2013; Blimpo & Pugatch, 2019; Eltanahy et al., 2020; Fejes et al., 2019; Pan & Akay, 2015). Some studies revealed that both conceptual knowledge (Aslan, 2021; Deveci, 2016; Deveci & Çepni, 2017; Inaltekin & Kirman-Bilgin, 2019; Samanci et al., 2020) and professional knowledge (İnaltekin et al., 2019) of pre-service science teachers in Türkiye of entrepreneurship are weak. Bayram and Çelik (2022) stated that the weak conceptual knowledge of entrepreneurship of pre-service science teachers can be enhanced through Technopark visits, while Kirman-Bilgin and İnaltekin (2022) found that it can be enhanced through both theoretical and practical training. Inaltekin and Kirman-Bilgin (2022) also stress that science teachers and pre-service science teachers require professional knowledge that can measure entrepreneurship skills. Based on the results and recommendations of these studies, we designed LSTG to conduct the present study and explored the extent to which it affects pre-service science teachers' professional knowledge of entrepreneurship skills.

Method

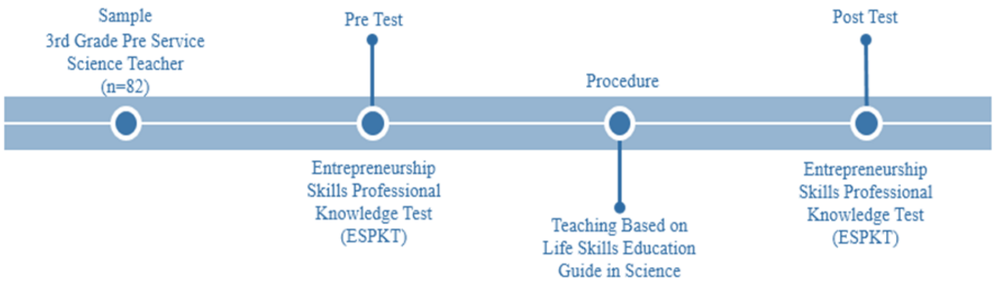

Figure 1. Single Group Pre and Post Test Experimental Design of the Study.

Research Design

The present study was a one-group pre-test-post-test experimental design. In this context, the effect of LSTG was tested on a single group. The experimental process for the study is illustrated in **Figure 1**.

Participants

The present study was conducted with 82 (65 female and 17 male) pre-service teachers studying in the third year (Class A and Class B) of the science education program of a public university in 2019-2020. The courses taken by the third-grade pre-service science teachers participating in the study before the study were Introduction to Educational Science, Atatürk's Principles and History of Turkish Revolution 1-2, Foreign Language 1-2, Turkish Language 1-2, Computer 1-2, General Physics 1-2-3, General Physics Laboratory 1-2-3, General Chemistry 1-2-3-4, General Chemistry Laboratory 1-2, General Biology 1-2, General Biology Laboratory 1-2, General Mathematics 1-2, Educational Psychology, Teaching Principles and Methods, Measurement and Evaluation, Introduction to Modern Physics, Science Technology Program and Planning, Chemical Analysis Methods. The courses they take during the study are Instructional Technologies and Material Design, Special Topics in Physics, Special Topics in Chemistry, Human Anatomy and Physiology, Statistics, Science Teaching Laboratory Practices 1, History of Turkish Education, and Scientific Research Methods. One of the researchers attended the Instructional Technology and Material Design course as an uninvolved observer. Based on these observations, it was concluded that the Instructional Technology and Material Design course did not cover the relevant content in parallel with the content of the experimental process. Pre-service teachers use the professional knowledge they have acquired up to their senior year in their internship during their senior year.

Therefore, it can be stated that the most suitable period for the study is the third grade. Moreover, pre-service science teachers take the Public Personnel Selection Examination in the fourth grade in order to be able to serve in the public sector after graduation. Considering that the pace and stress of studying for the exam would lead to a cognitive burden on the pre-service teachers, it was determined that the study was not suitable for the last grade level.

Research Context

Entrepreneurship education has become quite popular in Türkiye owing to both societal interest and political initiatives. Additionally, apart from training in institutional bodies such as the Small and Medium Enterprises Development Organization, various levels of education have been included in the system since 2018 (Ministry of National Education [MoNE], 2018). In 2018, domain-specific skills were added to the science curriculum as life skills (creative thinking, analytical thinking, entrepreneurship, communication, decision-making, and teamwork). These skills were introduced in the science curriculum from Grade 5 onwards, all subjects included activities to enable students to actively develop entrepreneurship skills under the title “Science, engineering and entrepreneurship practices”. This revised curriculum emphasizes the necessity for students to acquire the awareness of contributing to the economy through the use of their scientific knowledge. It is further stressed that students create innovations by using scientific knowledge to meet the challenges of life and that this aims to add value to societies, develop material culture and serve economic life (MoNE, 2018). Therefore, the acquisition of life skills based on entrepreneurship skills became one of the fundamental purposes of the science curriculum. Based on this purpose, pre-service science teachers must be equipped with the professional knowledge that will enable them to teach these skills to their students when they start working.

Research Procedures

In the present study, the first step was to finalize the procedures for the development of the LSTG. In this regard, interviews were initially conducted with 21 science educators from 11 universities, three from each of the seven regions, voluntarily. The types of activities and suggestions of the academicians participating in the study were identified to gain entrepreneurship skills professionally in the courses they conduct (Kirman-Bilgin et al., 2023). The draft activities were discussed with the participation of 21 science educators from the universities mentioned in the “Life Skills Education in Science Education Workshop” held in 2018, and the content of LSTG (Kirman-Bilgin, 2019) was finalized and made ready for the pilot scheme within the framework of the suggestions given. The pilot schemes were conducted with 69 students studying in the third-year science teaching program of a different public university in the spring semester of the 2018-2019 academic year. Following the pilot schemes, the LSTG was finalized. The main study was carried out in a total of 14 weeks within the scope of the "Science Teaching and Laboratory Practices-I" course, which has 4 weekly hours. In the main study, all the activities specified in the content of the practice were fulfilled and there was no timing problem. The stages of pre-service science teachers' teaching process based on LSTG are shown in **Table 1**.

The first week of the experimental process started with a discussion of the types of life skills and their place and importance in the secondary school science curriculum. Furthermore, LSTG was introduced and the tasks within the practice process were assigned. From the second week onwards, professional knowledge on the six life skills was introduced. Each week, pre-service teachers followed the guide to understand the type of life skill of that week, plan activities to help their students acquire this skill when they start their profession and work on measuring and evaluating the skill. The practiced LSTG aimed to enable pre-service teachers to approach entrepreneurship, which is related to other life skills, from a holistic perspective.

Data Collection

"Entrepreneurship Skills Professional Knowledge Test (ESPKT)" was implemented to determine the professional knowledge of pre-service science teachers on entrepreneurship. The test is designed by considering professional knowledge indicators for entrepreneurship skills. These indicators are as follows (Kirman-Bilgin, 2019, p.14):

- I1. Defines entrepreneurship skills.
- I2. Explain the characteristics of individuals with entrepreneurship skills.
- I3. Comprehends the indicators of entrepreneurship skills.
- I4. Designs materials on how to teach entrepreneurship skills to students in science courses.
- I5. Designs a measurement tool for how to measure entrepreneurship skills in science courses.
- I6. Designs an assessment tool for how to evaluate entrepreneurship skills after they are measured.

Based on the above-mentioned indicators, the ESPKT consists of 6 open-ended questions. There is one question for each indicator.

The questions in the test were developed by a science educator and subjected to validity studies by a science educator and a science teacher. Reliability studies were conducted with senior pre-service science teachers

Table 1. LSTG Teaching Process.

Week	Subject	Course Content
1	Life Skills	Introducing the skill learning area, discussing its place and importance in the science curriculum, explaining the problem-solving process, giving tasks to the pre-service teachers
2	Communication and Teamwork Skills	Defining communication and teamwork skills and discussion of their indicators
3		Discussion of model activities for teaching communication and teamwork skills to students
4		Discussion of the relevance of the activities designed by the pre-service teachers (Task 1) within the scope of the indicators
5		Discussion of model assessment and evaluation tools to measure these skills of students
6	Decision-Making and Entrepreneurship Skills	Defining decision-making and entrepreneurial skills and discussion of their indicators
7		Discussion of model activities for students to acquire decision-making and entrepreneurship skills
8		Discussion of the relevance of the activities designed by the pre-service teachers (Task 2) within the scope of the indicators
9		Discussion of model assessment and evaluation tools to measure these skills of students
10	Analytical Thinking and Creative Thinking Skills	Defining analytical thinking and creative thinking skills and discussion of their indicators
11		Discussion of model activities for teaching analytical thinking and creative thinking skills to students
12		Discussion of the relevance of the activities designed by the pre-service teachers (Task 3 and 4) within the scope of the indicators
13 14		Discussion of model assessment and evaluation tools to measure these skills of students
Tasks	Task 1: Design an original worksheet based on entrepreneurship skills to help your students develop communication and teamwork skills. Task 2: Design an original worksheet based on entrepreneurship skills to help your students develop decision-making and entrepreneurship skills. Task 3: Design an original worksheet based on entrepreneurship skills to help your students develop analytical thinking skills. Task 4: Design an original worksheet based on entrepreneurship skills to help your students develop creative thinking skills. Tasks 1 and 2 were carried out individually by pre-service teachers and Tasks 3 and 4 were carried out by teams.	

Table 2. Validity and Reliability Study of ESPKT Questions.

Prior to the Validity Study	Post Validity Study	Post Reliability Study
1. What is entrepreneurship?	1. What is entrepreneurial skill?	1. What is entrepreneurial skill?
2. What are the features of entrepreneurship?	2. What are the characteristics of individuals with entrepreneurial skills?	2. What are the characteristics of individuals with entrepreneurial skills? 3. What are the indicators of entrepreneurship skills?
3. Design an activity that can provide this skill.	3. What kind of activity would you use to teach entrepreneurship skills? Design your activity.	4. What kind of activity would you use in science classes to teach entrepreneurship skills? Design your activity.
4. How do you measure and assess this skill?	4. What kind of a tool would you use to measure entrepreneurship skills? Design your tool.	5. What kind of measurement tool would you use to measure your students' entrepreneurial skills? Design your tool.
	5. What kind of a tool would you use to assess entrepreneurial skills? Design your tool.	6. What kind of assessment tool would you use to assess your students' entrepreneurial skills after measuring them? Design your tool.

(n=21). The information on how the questions in the ESPKT evolved during the validity and reliability studies is given in **Table 2**:

ESPKT was finalized and ready for the main study after the necessary adjustments.

Data Analysis

The data obtained from the ESPKT were subjected to content analysis. The secondary school science course entrepreneurship skill indicators (Kirman-Bilgin, 2019, p.16) used to measure how much the objective was achieved within the scope of questions 3, 4, and 5 of the ESPKT are as follows.

1. Business idea development
2. Emphasizing that the business idea is different from other business ideas
3. Setting short-term goals
4. Setting the market share target
5. Identifying potential customers
6. Perform competitor analysis
7. Determining the channels of reaching the customer
8. Drawing a workflow chart
9. Determining the duties and responsibilities of the personnel
10. Calculating the expenses of your business
11. Calculating the income of your business
12. Calculating the profit of your business
13. Marketing your product
14. Considering these indicators, a rubric was prepared to analyze the data obtained from the ESPKT. The rubrics for the assessment of professional knowledge of entrepreneurship skills in science prepared within the scope of this research are as in **Table 3** and **Table 4**.

The lowest possible score on the ESPKT is 0 and the highest possible score is 61. The pre-and post-test answers of the student coded P_{29} (preservice teacher number 29) to question 1 of the GBMBT are shown below:

A sociable, outspoken person who can easily adapt to environments (P_{29}'s pre-test response)

The ability to generate business ideas. The ability to further develop in a way that is beneficial to society, useful, economical, and does not damage the natural balance (P_{29}'s post-test response)

P_{29} received a score of "0" because his pre-test answers to the first question of the test did not cover the key concepts of seizing opportunities

Table 3. Criteria and Scoring Systematics for the Analysis of Data Obtained from the ESPKT.

Question	Analysis
1	Opportunity and economy codes need to be specified in the definition. One point is awarded for each code. The maximum possible score for the question is 2.
2	Feature 1: Assertive-Attack / Feature 2: Persuasive-Confident / Feature 3: Has Teamwork Skills / Feature 4: Has Problem-Solving Skills / Feature 5: Has Decision-Making Skills / Feature 6: Has Communication Skills / Feature 7: Risk Takes- Courageous / Feature 8: Curious-Observes / Feature 9: Has Creative Thinking Skills / Feature 10: Has a plan One point is awarded for each answer indicating each feature. The maximum possible score for the question is 10.
3	One point is awarded for each indicator of entrepreneurship skill. The maximum possible score for the question is 13.
4	It is considered that the designed activities consist of drawing attention or introducing, implementing, and assessing the activity. Considering these features, 1 point is given for attracting attention or introducing the activity, 2 points for implementing the activity, and 1 point for assessing the activity. One point is given for associating the activity with daily life. One point is awarded for each indicator covered by the designed activity (13 points in total). Writing only the name of the activity is awarded 0 points. The maximum possible score for the question is 18.
5	One point is given for each indicator of entrepreneurial skill addressed in the measurement tool. One point is awarded for meaningful categories created. One point is awarded for meaningful scoring of categories. One point is awarded for indicating the highest and lowest score. The maximum possible score for the question is 16.
6	A classification based on the lowest and highest possible score (e.g., a classification such as "demonstrated entrepreneurial skills at the desired level" - "demonstrated entrepreneurial skills at the desired intermediate level" - "did not demonstrate entrepreneurial skills at the desired level") is awarded 1 point. The answer emphasizing the point range of the classification is awarded 1 point. The maximum possible score for the question is 2.

Candidates are awarded 0 points for a meaningless answer, an irrelevant answer, or no answer for each question.

Table 4. Rubric of Development Level of Candidates' Professional Knowledge of Entrepreneurship Skills.

Score Interval	Assessment	Code
0-11	Professional knowledge of the skill is quite inadequate.	A
12-23	Professional knowledge of this skill is at a weak level.	B
24-35	Professional knowledge of this skill is at a moderate level.	C
36-48	Professional knowledge of this skill is at a good level.	D
49-61	Professional knowledge of this skill is at a very good level	E

and the economy. The post-test response was awarded "2" points as it emphasized both key concepts.

The rubric in which the total score of the development level of preservice teachers' professional knowledge of entrepreneurship skills is assessed is shown in **Table 4**.

Table 5. Wilcoxon Signed-Rank Test Results of the Data Obtained from ESPKT.

Posttest - Pretest	n	Mean Rank	Rank Sum	z	p
Negative rank	0	00.00	00.00	7.86	.000
Positive rank	82	41.50	3403.00		
Equal	0				
* Based on Negative Rank					

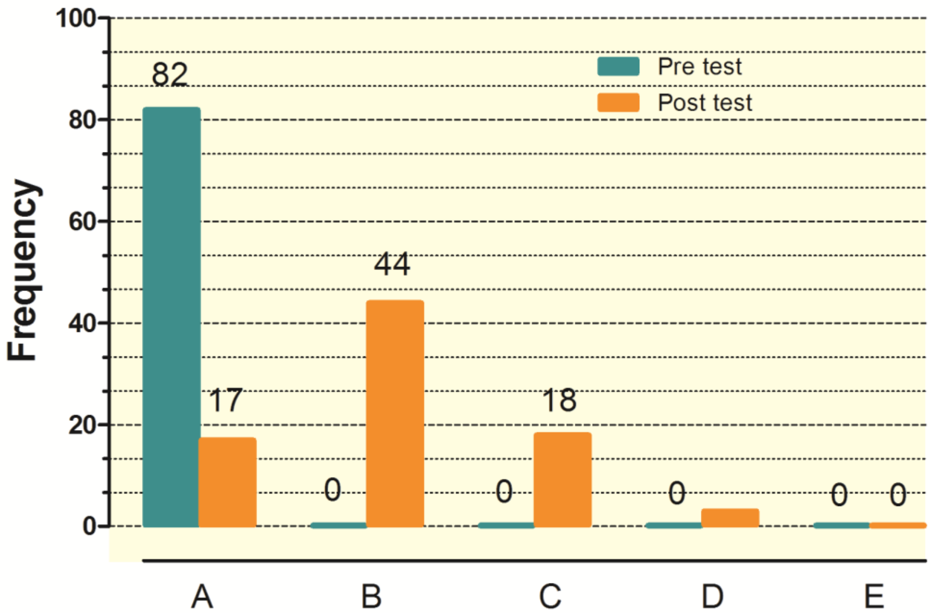

Figure 2. The Level of Professional Knowledge of Pre-service Science Teachers for Entrepreneurship Skills. *A: Professional knowledge of the skill is quite insufficient. B: Professional knowledge of the skill is at a weak level. C: Professional knowledge of the skill is at a moderate level. D: Professional knowledge of the skill is at a good level. E: Professional knowledge of the skill is at a very good level.*

In this regard, the data obtained from the ESPKT as pre-test and post-test were initially scored. The data obtained were analyzed using the Wilcoxon signed-rank test for related measures. Subsequently, the pre-and post-study progress of the pre-service teachers who participated in the study in the context of each question of the ESPKT was displayed in the form of graphs.

The graphs were accompanied by direct quotations from the pre-service science teachers' opinions (See Appendix A). In the data analysis using content analysis, pre-service teachers were coded as P_1, P_2.

Results

In order to find an answer to the research question "What is the effect of the life skills training guide in science on the development of third-year pre-service science teachers' professional knowledge of entrepreneurship skills?", the Wilcoxcon signed-rank test analysis findings of the pre-test and post-test scores of the pre-service science teachers are presented in **Table 5**.

The results of the analysis demonstrate that there is a significant difference between the pre-and post-experiment ESPKT scores of the candidates participating in the study ($z = 7.86$, $p < 0.05$). When the rank averages and sums of the difference scores are taken into consideration, it is revealed that the difference is in favor of the post-test score. The findings of the analysis of the effect of LSTG-based education on the development of pre-service science teachers' professional knowledge of entrepreneurship skills are presented in **Figure 2**.

When **Figure 2** is examined, it is evident that all of the pre-service science teachers' professional knowledge of entrepreneurship skills was quite inadequate before the implementation of the LSTG. After the application of the LSTG, it was observed that more than half of the pre-service teachers ($f = 44$) improved their professional knowledge level to a weak level. It was concluded that some of the pre-service teachers ($f = 18$) improved their professional knowledge to a moderate level and very few ($f = 3$) to a good level. However, at the end of this experimental process, it was realized that none of the pre-service science teachers were able to improve their professional knowledge of entrepreneurship skills to a very good level. The findings from each question of the test are presented in more depth as follows. The analysis findings obtained from the first question of the ESPKT are presented in **Figure 3**.

It was detected that 56 pre-service teachers used the key concept of seizing opportunities before the study and 81 pre-service teachers used it after the study (**Figure 3**). It was detected that 16 pre-service teachers used the key concept of the economy before the study and 53 pre-service teachers used it after the study it is apparent that there was a significant decrease in the number of candidates who gave meaningless answers and those who did not answer at all after the experimental process. The findings of the analysis obtained from the second question of the ESPKT are presented in **Figure 4**.

When the pre-test and post-test findings of the LSTG were analyzed, the number of pre-service teachers who emphasized the feature "has com

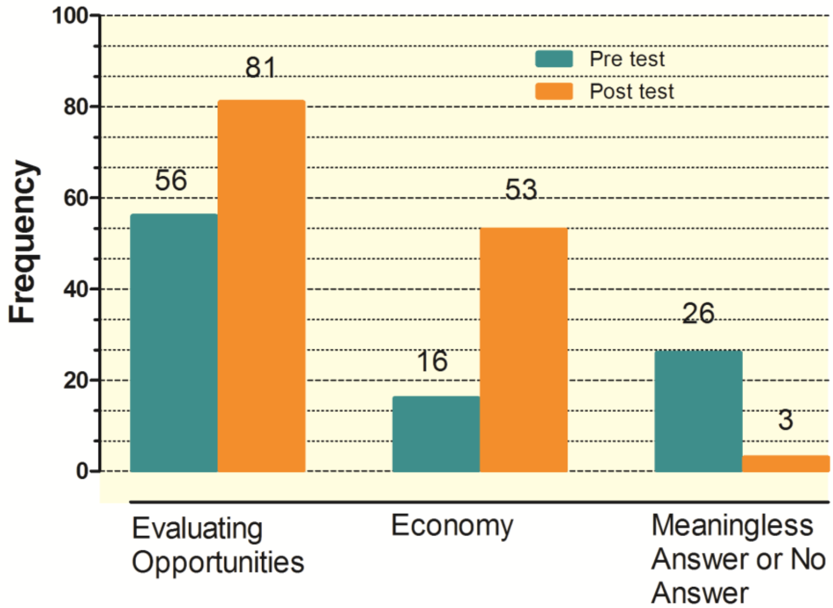

Figure 3. The Analysis Results of Related to Changes in Definitions of Entrepreneurial Skills of Pre-service Science Teachers.

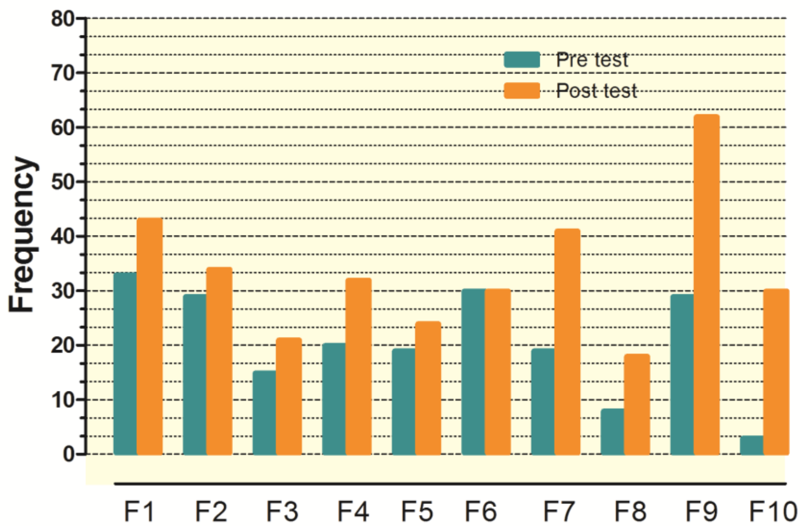

Figure 4. The Analysis Results of Related to Changes of Pre-service Science Teachers in Defining the Characteristics of Individuals with Entrepreneurial Skills. *Note: A pre-service teacher may have responded to more than one code in their answer. Feature 1: Assertive-Attack / Feature 2: Persuasive-Confident / Feature 3: Has Teamwork Skills / Feature 4: Has Problem-Solving Skills / Feature 5: Has Decision-Making Skills / Feature 6: Has Communication Skills / Feature 7: Risk Takes- Courageous / Feature 8: Curious-Observes / Feature 9: Has Creative Thinking Skills / Feature 10: Has a plan.*

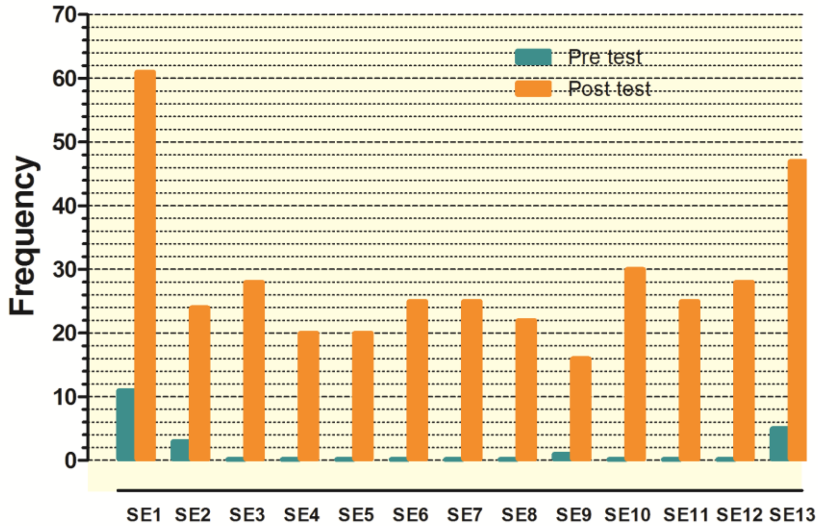

Figure 5. The Analysis Results of Regarding Changes in Defining Indicators of Entrepreneurial Skills of Pre-service Science Teachers. *Note: A pre-service teacher may have responded to more than one code in their answer. Indicators: SE1. Business idea development; SE2. Emphasizing that the business idea is different from other business ideas; SE3. Setting short-term goals; SE4. Setting the market share target; SE5. Identifying potential customers; SE6. Perform competitor analysis; SE7. Determining the channels of reaching the customer; SE8. Drawing a workflow chart; SE9. Determining the duties and responsibilities of the personnel; SE10. Calculating the expenses of your business; SE11. Calculating the income of your business; SE12. Calculating the profit of your business; SE13. Marketing your product.*

munication skills" did not change (**Figure 4**). The most striking increase in the number of pre-service teachers expressing the features of entrepreneurial individuals was in "has creative thinking skills" and "has a plan". The findings of the analysis obtained from the second question of the ESPKT are presented in **Figure 5**.

When **Figure 5** is analyzed, the increase in the number of pre-service teachers emphasizing the indicators "Business idea development and Marketing your product" at the end of the experimental process is higher than the other indicators. The findings of the analysis obtained from the second question of the ESPKT are presented in **Figure 6**.

When **Figure 6** is analyzed, there was a significant increase in the number of pre-service teachers who included attention-grabbing and active engagement sections in the activities designed after the experiment. However, it is noteworthy that no pre-service teacher addressed the evaluation section before and after the experiment. Before the experimental process, it was observed that only one pre-service teacher designed an activity related to daily life. After the implementation of LSTG, it was seen that 45 pre-service

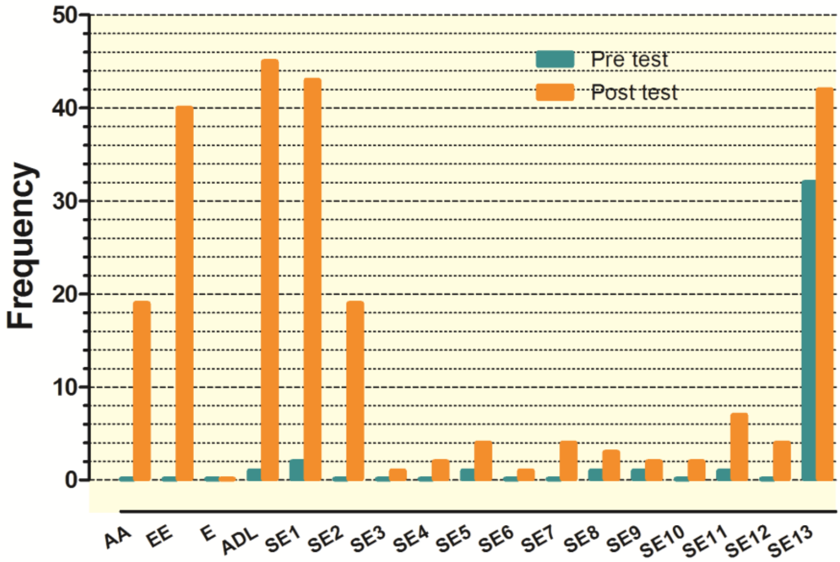

Figure 6. The Analysis Results of Regarding Changes in the Activities Designed to Gain Entrepreneurial Skills for Students of Pre-service Science Teachers. *AA: Attracting Attention / EE: Efficient Engagement / E: Evaluation / ADL: Associating with Daily Life / SE1. Business idea development; SE2. Emphasizing that the business idea is different from other business ideas; SE3. Setting short-term goals; SE4. Setting the market share target; SE5. Identifying potential customers; SE6. Perform competitor analysis; SE7. Determining the channels of reaching the customer; SE8. Drawing a workflow chart; SE9. Determining the duties and responsibilities of the personnel; SE10. Calculating the expenses of your business; SE11. Calculating the income of your business; SE12. Calculating the profit of your business; SE13. Marketing your product.*

teachers included activities associated with daily life. After the experiment, there was a significant increase in the number of pre-service teachers who included the indicators "*Develops a business idea (f = 43) and Emphasizes that the business idea is different from other business ideas* (f = 19)" in their activities. The findings obtained from the fifth question of the ESPKT are shown in **Figure 7**.

When **Figure 7** is analyzed, it was found that there was a significant increase in the number of pre-service teachers who addressed the indicators of entrepreneurship skills in the measurement tool they prepared after the experimental process. Furthermore, there was a significant increase in the number of pre-service teachers who indicated the lowest and highest scores that could be obtained from the measurement tool, categorization, and scoring processes after the implementation of the LSTG. The findings obtained from the last question of the ESPKT are shown in **Figure 8**.

When **Figure 8** was analyzed, it was seen that there was a remarkable increase in the number of pre-service teachers who designed an assess

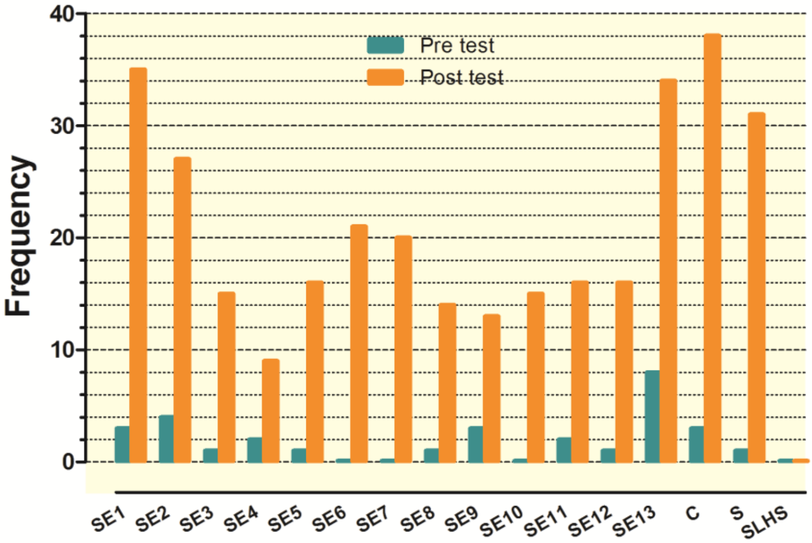

Figure 7. The Analysis Results of Regarding Changes in Tools Designed to Measure Students' Understanding of Entrepreneurial Skills of Pre-service Science Teachers. *C: Categorization / S: Scoring / EDEYPB: Specifying the Lowest and Highest Score; SE1. Business idea development; SE2. Emphasizing that the business idea is different from other business ideas; SE3. Setting short-term goals; SE4. Setting the market share target; SE5. Identifying potential customers; SE6. Perform competitor analysis; SE7. Determining the channels of reaching the customer; SE8. Drawing a workflow chart; SE9. Determining the duties and responsibilities of the personnel; SE10. Calculating the expenses of the enterprise; SE11. Calculating the income of your business; SE12. Calculating the profit of your business; SE13. Marketing your product.*

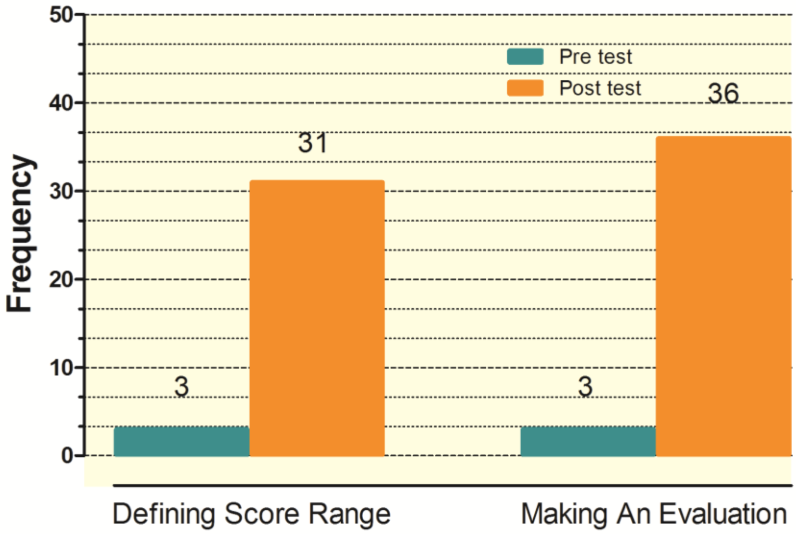

Figure 8. The Analysis Results of Regarding Changes in Tools Designed to Assess Students' Understanding of Entrepreneurial Skills of Pre-service Science Teachers.

ment tool with the features of "specifying a score range and making an evaluation" at the end of the experimental process.

Discussion and Results

This study provides evidence for the effectiveness of a guide that can be used to improve pre-service science teachers' professional knowledge of entrepreneurship skills. Quantitative findings showed that the implementation of the LSTG increased pre-service science teachers' professional knowledge of entrepreneurship skills. Presentation of sample activities and measurement tools on entrepreneurship skill professional knowledge in the experimental process, pre-service teachers` designing activities to develop this skill, and having in-class discussions can be seen as the main factors in increasing their professional knowledge. However, the qualitative findings showed that at the end of the experimental process, the pre-service science teachers did not increase their professional knowledge to good and very good levels (**Figure 2**). It can be said that this result indicates that it is difficult for pre-service science teachers to gain professional knowledge of entrepreneurship skills in a 14-week period. Scriven (1994) emphasizes that acquiring professional knowledge in the teaching profession is a long-lasting process. Bolaji (2012) and Inaltekin et al. (2019) found that pre-service science teachers have characteristics with low professional knowledge on entrepreneurship. The researchers emphasize that the reason for this is the lack of resources to comprehend professional knowledge about entrepreneurship skills in science teacher training programs. There is also a similar situation when the science teacher training program in Türkiye is examined. Although life skills are targeted to be acquired by students in the secondary school science curriculum, there is no professional knowledge course on life skills in the teacher training program. This situation stands out as the biggest deficiency of this program. Therefore, it can be concluded that the implemented guideline offers rich theoretical and practical content in developing pre-service teachers' professional knowledge on entrepreneurship skills. However, it was also revealed that the guideline proposed in this study should be implemented over a longer period and its content should be enriched. The reason was that although the quantitative data showed that the pre-service teachers' professional knowledge increased, the qualitative data showed that the experimental process was not sufficient. Another reason why pre-service science teachers' professional knowledge about entrepreneurship skills did not increase to a good or very good level may be due to insufficient prior knowledge. Because insufficient prior knowledge is a factor that makes it difficult to learn new information (Otero & Nathan, 2008), entrepreneurship skill, which is a life skill, was included in the curriculum of science education in Türkiye in 2013. Therefore, science educators have also started to work on this concept as of this year. The insufficient knowledge of science educators about entrepreneurship skills can also be seen as another reason for the weak prior knowledge of the pre-service teachers. Aslan (2021), Bayram and Çelik (2022), and Samanci et al. (2020) found that pre-service science teachers' conceptual knowledge of entrepreneurship was insufficient. The same situation also emerged in the current study. The findings obtained from the second question of the test, which probed conceptual knowledge on entrepreneurship, showed that at the end of the experimental process, the pre-service science teachers had difficulty in listing the characteristics of entrepreneurial individuals. This situation may have negatively affected the pre-service teachers' professional knowledge acquisition process. The reason is that a pre-service teacher's lack of knowledge about a concept makes it difficult for him/her to use his/her professional knowledge to teach this concept (Gess-Newsome et al., 2019). Tiernan (2016) emphasizes that when field-specific entrepreneurship education is provided, pre-service teachers develop positive attitudes towards entrepreneurship. When we consider that this guide covers a training content for entrepreneurship in science education, the fact that the pre-service teachers can associate entrepreneurship with science and understand the importance of using this skill in the field can be seen as another reason for the increase in their professional knowledge. Because pre-service teachers' inability to internalize entrepreneurship (Chen et al., 2015; Gautam & Singh, 2015; Pihie & Bagheri, 2011; Seikkula-Leino et al., 2010; Ruskovaara & Pihkala, 2013) makes it difficult to acquire professional knowledge (Flores, 2015).

One of the results of the research is that there was a significant increase in the number of pre-service teachers who emphasized the indicators for entrepreneurial skills after the experiment. It was found that the number of pre-service teachers who emphasized the indicators "*develops a business idea*" and "*markets the product*" was higher than the number of pre-service teachers who emphasized the other indicators. The same result was also found in the activities prepared by the pre-service teachers to develop students' entrepreneurial skills. In Türkiye, it is recommended to organize year-end entrepreneurship festivals in the curriculum of science education courses (MoNE, 2018). In such festivals, students market the products they develop within the scope of the course. Therefore, the reason why the pre-service teachers addressed the indicators of "*develops a business idea*" and "*markets the product*" may be due to the emphasis in the program. Another result of the study showed that the guide was very effective in linking science outcomes with entrepreneurship-based daily life problems in the worksheets designed by the pre-service teachers. It was found that the pre-service teachers did not include evaluation (assessment of the learning outcome) as the third part in the worksheets they designed to develop students' entrepreneurship skills. It can be said that this situation indicates that their professional knowledge about designing worksheets is also weak. When **Figures 6** and **7** were analyzed comparatively, it was found that although the number of pre-service teachers using entrepreneurship skill indicators in their activities was low, it was more than those using them in the measurement tool. During the experimental process, the pre-service teachers also took the Instructional Technology and Material Design course. Therefore, the pre-service teachers were involved in the process of designing an activity for the first time with this course. This may be the reason why the pre-service teachers had difficulty in designing the entrepreneurship-based worksheet and adapting the indicators in this study. Pektaş and Çelik (2021) found that pre-service science teachers were good at directing students to innovate in the activities they designed but lacked in directing students to take risks. The current study also showed that the number of pre-service science teachers (SE2) who paid attention to creating original work ideas in the worksheets they designed after the experimental process increased. However, the current study did not provide any professional training on risk-taking. This can be seen as a limitation of the study. The implemented guideline had a positive effect on the number of pre-service teachers who emphasized the features of scoring, categorizing, indicating score ranges, and making evaluations when designing assessment and evaluation tools. However, the number of pre-service teachers emphasizing these features was still less than half of the participants. The LSTG did not have any effect on the pre-service teachers' process of indicating the lowest and highest score. Although the candidates took the measurement and evaluation course in the second year, this result may be an indication that the candidates had difficulty in designing measurement instruments. The fact that the measurement and evaluation process is inherently difficult (Wilson & Martinussen, 1999) may be the reason why the pre-service teachers also had difficulties.

Implications

This study showed that the professional knowledge of teachers about teaching entrepreneurship can be developed by pre-service science teachers through theoretical and practical training, although not at the desired level. Based on this result of the study, science educators are recommended to enrich the content of LSTG and extend the training process. The content of LSTG can be enriched by giving more space to activity development activities that aim to integrate the entrepreneurship skill indicators of the pre-service teachers with science activities. It is seen that the one-week (four hours) content in the guide for measuring entrepreneurship skills is not sufficient to develop pre-service teachers' professional knowledge in this field. At the same time, in the content of the measurement and evaluation course, only subject-oriented procedures are carried out. Therefore, education policymakers may be advised to add the skills learning area to the content of this course. Science educators are advised to make applications for the entrepreneurship skills of the pre-service science teachers in other professional knowledge courses. In order for science teacher candidates to develop their conceptual knowledge about entrepreneurship and to internalize the subject, activities that bring together entrepreneurs and pre-service science teachers can be organized in science teacher education programs.

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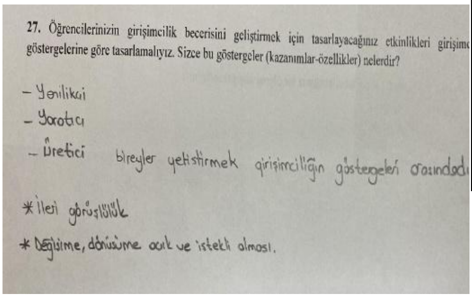
Appendix A:

Excerpts from the Pre- and Post-Test Responses of Pre-Service Teachers to the ESPKT

Excerpts from Pre-Service Teachers' Identification of Indicators of Entrepreneurship Skills
(Excerpts from the Pre- and Post-Test Answers of the pre-service teacher coded P_{54} to Question 3 of the ESPKT)

27. The activities you design to develop your students' entrepreneurship skills should be designed according to the indicators of entrepreneurship skills. What do you think these indicators (gains features)
To raise individuals who are -Innovative, -Creative -Productive is among the indicators of entrepreneurship. *Forward-thinking, *Open to change

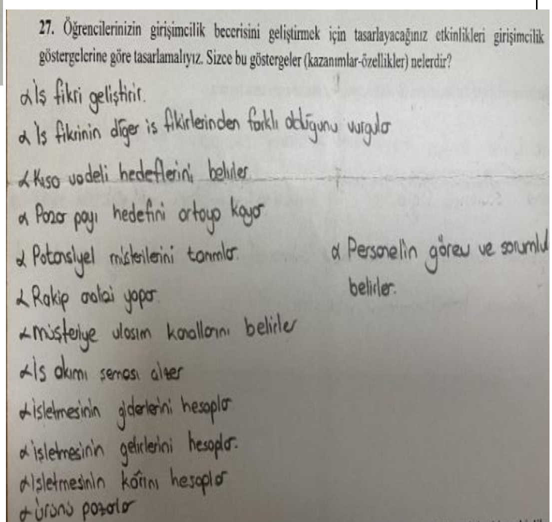

27. Öğrencilerinizin girişimcilik becerisini geliştirmek için tasarlayacağınız etkinlikleri girişim[cilik] göstergelerine göre tasarlamalıyız. Sizce bu göstergeler (kazanımlar-özellikler) nelerdir?

– Yenilikçi
– Yaratıcı
– Üretici bireyler yetiştirmek girişimciliğin göstergeleri arasında
*İleri görüşlülük
*Değişime, dönüşüme açık ve istekli olması.

Pre-Test

P_{54}'s answer to this question in the post-test: "To raise individuals who are innovative, creative, forward-thinking, open to change,and productive."

27. The activities you design to develop your students' entrepreneurship skills should be designed according to the indicators of entrepreneurship skills. What do you think these indicators (gains features) are?
*Develops a business idea; *Emphasizes that the business idea is different from other business ideas; *Determines short-term goals; *Sets a market target; identifies potential customers; *Makes competitor analysis; *Determines transportation channels; *Draws a business plan; *Calculates the expenses of the business; *Calculates the income of the business; *Calculates the profit of the business; *Markets the product and determines the duties and responsibilities of staff


27. Öğrencilerinizin girişimcilik becerisini geliştirmek için tasarlayacağınız etkinlikleri girişimcilik göstergelerine göre tasarlamalıyız. Sizce bu göstergeler (kazanımlar-özellikler) nelerdir?

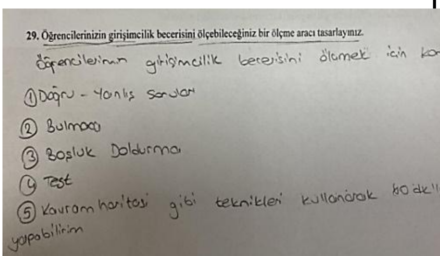
α İş fikri geliştirir.
α İş fikrinin diğer iş fikirlerinden farklı olduğunu vurgular
α Kısa vadeli hedeflerini belirler
α Pazar payı hedefini ortaya koyar
α Potansiyel müşterilerini tanımlar
α Rakip analizi yapar
α müşteriye ulaşım kanallarını belirler
α İş akım şeması çizer
α işletmesinin giderlerini hesaplar
α işletmesinin gelirlerini hesaplar.
α işletmesinin kârını hesaplar
α ürünü pazarlar
α Personelin görev ve sorumlul[uklarını] belirler.

Post Test

P_{54}'s answer to this question in the post-test: "Develops a business idea; emphasizes that the business idea is different from other business ideas; determines short-term goals; sets a market target; identifies potential customers; makes competitor analysis; determines transportation channels; draws a business plan; calculates the expenses of the business; calculates the income of the business; calculates the profit of the business; markets the product and determines the duties and responsibilities of the staff."

Excerpts from the Tools Designed by the Pre-Service Teachers to Measure Whether Secondary School Students Acquire Entrepreneurship Skills (Excerpts from the Pre- and Post-Test Answers of the Pre-Service Teacher Coded P_{66} to the 5th Question of ESPKT)

29. Design an assessment tool to measure your students' entrepreneurship skills.
In order to measure students' entrepreneurial skills, I can make a 60-minute exam on the subject by using techniques such as;
    1. True – False Questions
    2. Puzzles
    3. Gap-filling
    4. Multiple Choice
    5. Mind Map

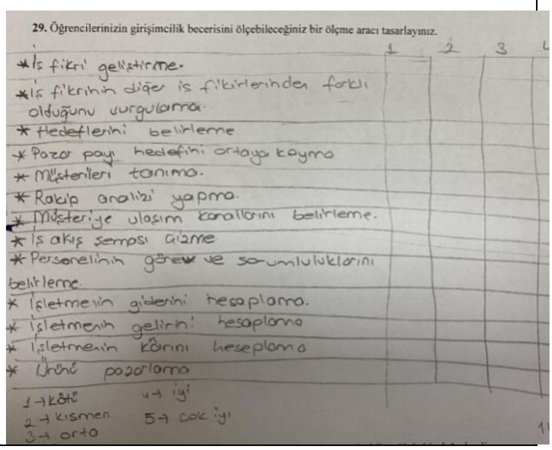

29. Öğrencilerinizin girişimcilik becerisini ölçebileceğiniz bir ölçme aracı tasarlayınız.
Öğrencilerimin girişimcilik becerisini ölçmek için ko
① Doğru - Yanlış Sorular
② Bulmaca
③ Boşluk Doldurma
④ Test
⑤ Kavram haritası gibi teknikleri kullanarak 60 dk'l
yapabilirim

Pre-Test

P_{66}'s answer to this question in the pre-test: "In order to measure students' entrepreneurial skills, I can make a 60-minute exam on the subject by using techniques such as true and false questions; puzzles; gap-filling; multiple choice and mind map."

29. Design an assessment tool to measure your students' entrepreneurship skills.

	1	2	3	4
Developing a business idea				
Emphasizing that the business idea is different from other				
Setting goals				
Setting the market share				
Getting to know customers				
Competitor analysis				
Determining customer access				
Drawing a workflow chart				
Determining the duties and responsibilities of staff				
Calculating business				
Calculating business income				
Calculating business profit				
Marketing the Product				
Poor Fair Average Good Very good				


29. Öğrencilerinizin girişimcilik becerisini ölçebileceğiniz bir ölçme aracı tasarlayınız.

	1	2	3	4
* İş fikri geliştirme.				
* İş fikrinin diğer iş fikirlerinden farklı olduğunu vurgulama.				
* Hedeflerini belirleme				
* Pazar payı hedefini ortaya koyma				
* Müşterileri tanıma.				
* Rakip analizi yapma.				
* Müşteriye ulaşım kanallarını belirleme.				
* İş akış şeması çizme				
* Personelinin görev ve sorumluluklarını belirleme.				
* İşletmenin giderini hesaplama.				
* İşletmenin gelirini hesaplama				
* İşletmenin kârını hesaplama				
* Ürünü pazarlama				

1 → kötü 4 → iyi
2 → kısmen 5 → çok iyi
3 → orta

	Post Test P66's answer to this question in the post-test: "Developing a business idea; emphasizing that the business idea is different from other business ideas; setting goals; setting market share target; getting to know customers; competitor analysis; determining customer access channels; drawing a workflow chart; determining the duties and responsibilities of staff; calculating business expenses; Calculating business income; calculating business profit and marketing the product." "Scoring: poor (1 point); fair (2 points); average (3 points); good (4 points) and very good (5 points)"

ORIGINAL ARTICLE

Protocol-Guided Teaching in Secondary Chemistry Education: An Analysis of the Learning Protocol for the Instruction of Omnipresent $CaCO_3$ Based on Student Life Experiences

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***Abstract**: Protocol-guided teaching is a student-centered instruction paradigm in which teachers compose learning protocols in advance to guide students through the entire learning process in an effort to foster in them the capacity for autonomous learning. Effective learning protocols can have a substantial impact on classroom outcomes. The purpose of this article is to evaluate the significance of protocol-guided teaching in chemistry education through an examination of a learning protocol designed for the instruction of omnipresent $CaCO_3$. This protocol emphasizes learning based on real-world experience.*

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Keywords: *Protocol-Guided Teaching Model, Autonomous Learning, Secondary Chemistry Education*

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Conflict of Interests: *None*

T*HE Basic Education Course Standards for Chemistry 2022* issued by the Ministry of Education of China emphasize that chemistry education should fully utilize student life experiences and experiment-predominant exploratory activities to achieve heuristic instruction in order to cultivate students' autonomous learning ability (Ministry of Education of China, 2022). The protocol-guided teaching model arose as a significant experiment in teaching paradigm innovation in the context of basic education reform. It adheres to the educational principle of student-centered classroom instruction, shifting from teachers' unilateral knowledge transmission to teacher-student collaboration and from an emphasis on student learning outcomes to an emphasis on the learning process (Wang, 2022). In protocol-guided instruction, teachers construct learning protocols for students in advance based on course standards, textbook content, and student learning conditions. Typically, learning protocols consist of learning objectives, materials, methods, and procedures, and instructors use them to guide students toward more independent learning. Protocol-guided instruction relies on well-designed learning protocols for its effective implementation.

This article analyzes a lesson that junior secondary students learned about "omnipresent $CaCO_3$" using the "Four Steps of Guidance" method of protocol-guided instruction. The learning protocol's four primary parts are student preparation before class, summary and reflection, classroom inquiry, and instructional assessment. The four components work together to build a complete methodology. It can be used as a framework for managing the classroom as well as a learning plan for students. The learning procedure fully incorporates the practice and life experiences of the students.

Before-Class Preparation

The learning protocol includes a variety of pre-class learning activities designed to guide students in observing real-world events related to course content, integrating themselves into learning contexts, and formulating questions for the forthcoming classroom study. Prior to this session, students had a basic understanding of the reaction between calcium carbonate ($CaCO_3$) and dilute hydrochloric acid to produce CO_2, as well as the reaction between clear limewater and CO_2. Students are also familiar with calcium compounds such as limestone, marble, quicklime, and slaked lime. The pre-class learning protocol for the current lecture is as follows:

Comprehending the Learning Objectives of this Lesson

- Discover how to identify $CaCO_3$.

- Learn the use of $CaCO_3$ in manufacturing and living, as well as industrial $CaCO_3$ production methods, and discover how to prepare $CaCO_3$ in the lab and at home.
- Understand the chemical research process, from experiment to phenomenon, conclusion, and application.

(*The purpose of this procedure is to provide students with a foundational understanding of the content and methods of this lesson and to emphasize the most important aspect of this session, namely the identification of $CaCO_3$.*)

Pre-Class Learning Tasks

- Task one: Try to answer the following two questions:

To remove a small amount of scale in the kettle at home, you can wash it with:

A. Vinegar
B. Dish soap
C. Salt water
D. Water after rice rinsing

The inner wall of the beaker that has held limewater for an extended period of time is coated with a white solid, which has the chemical formula ___________. Remove this layer of white solid using a reagent with a reaction of ___________________________ (in a chemical equation).

- Task two: Create a profile for $CaCO_3$.
- Task three: Identify $CaCO_3$-containing substances in everyday life and bring samples to class.
- Task four: Formulate $CaCO_3$-related questions based on knowledge gained from all pre-class learning activities.

(*This procedure is intended to implement the theory of life-based learning in chemistry education. The purpose of the first task's two exercises is to cultivate students' awareness of solving real-world problems with chemical knowledge and to prompt them to review prior $CaCO_3$-related knowledge. This lesson's third task is designed to encourage students to seek out more extensive information about $CaCO_3$ using digital media and to increase their interest in learning. The purpose of Task 4 is to allow students to recognize chemical components in everyday substances and to make them aware of the pervasiveness of chemistry in our lives. On the basis of these pre-class learning activities and relevant textbook section readings, students pose queries* *that they wish to gain a deeper understanding of in subsequent learning processes.*)

Classroom Inquiry

Activity-based learning can increase student engagement in the classroom and help them develop their analytical and problem-solving abilities. Plans that are well structured can help teachers accomplish the learning objectives and considerably increase the efficacy of inquiry-based learning in the classroom. This lesson's learning protocol for the class inquiry follows the formula "question + activity."

i. Question One: How do I identify $CaCO_3$?

Activity: Using laboratory equipment, determine whether the specimens collected at home contain $CaCO_3$ and document the experimental procedures using **Table 1**.

Table 1. Lab Experiments on Specimens Collected at Home.

Specimens	Experiment Design	Experimental Phenomena	Experiment Conclusions

(*Based on the general path of scientific inquiry: question—hypothesis—research design—experimentation or literature review—conclusion, students are required to engage in group discussion to develop an experiment design using instruments and chemicals available in the lab and to conduct the experiments in groups to determine whether their home specimens contain $CaCO_3$. Among students, there are generally two prominent experimental methods: (i) Burn the solid specimen over an alcohol flame, place it in a test tube with water, and then add phenolphthalein drop by drop to observe the liquid turn red; (ii) Place the specimen in a test tube and add diluted hydrochloric acid drop by drop to produce bubbles; the gas produced is then introduced into clear limewater to make it turbid. Students tend to believe that either of the two phenomena can determine the presence of $CaCO_3$ in their specimens. The teacher then instructs the students to conduct one more experiment, which involves dripping diluted hydrochloric acid into a test container containing a chemical whose name is concealed and comparing the experimental phenomenon to that of the second of the preceding methods. The same phenomenon is observed, and students have discovered that the compounds used in the experiment are carbonates other than calcium car-*

bonate. Students recognize at this point that their experimental methods are insufficient, as they can only determine that the tested substance is carbonate. To establish that it is $CaCO_3$, they must demonstrate that it contains the element calcium. To stimulate students' interest in further chemistry study, the teacher can demonstrate how to identify calcium in a compound through a flame reaction, which will be taught at the senior secondary level.)

ii. *Question Two: What Is the Use of $CaCO_3$?*

Activity: Students present the information on the applications of $CaCO_3$ that they gathered prior to class.

(*The purpose of this activity is to reinforce students' comprehension of the chemical concept that a substance's use is determined by its properties*.)

iii. *Question Three: How to Make $CaCO_3$ with High Purity on an Industrial Scale*

Activity one: Watch a video about survival in the wild that incorporates the process of using shells to produce $CaCO_3$ of high purity.

(*After watching this video, students evaluate the procedure's logic and understand how $CaCO_3$, CaO, and $Ca(OH)_2$ are converted, preparing them for the discussion that follows on the large-scale manufacture of high-purity $CaCO_3$. Students learn through this practice that chemistry knowledge can be applied to save lives on occasion*.)

Activity two: Students have conversations in groups about how to make high-purity $CaCO_3$. Each group develops an experimental design that will be assessed by other groups based on their understanding of the characteristics of $CaCO_3$ and its presence in the environment. The uniform experiment method will be chosen based on the most logical strategy.

(*This activity is intended to enhance students' ability to design experiment methods and evaluate the applicability of knowledge*.)

Activity three: Students prepare $CaCO_3$ in the laboratory using carbide slag as a source material to simulate the industrial production of $CaCO_3$.

(*This experiment gives students the opportunity to comprehend how industrial production may transform waste into useful materials and to cultivate awareness of the prudent use of resources*.)

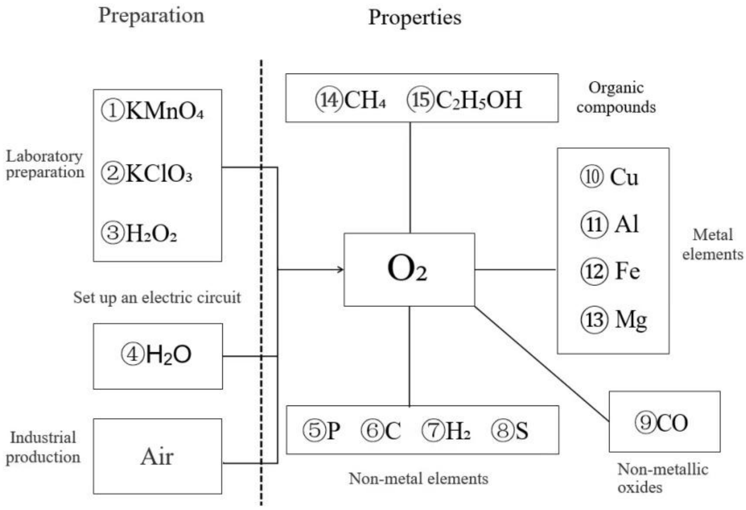


Figure 1. A Basic Knowledge Structure of O_2.

Summary and Reflection

The purpose of the summary and reflection procedure is to encourage students to derive research methods from classroom inquiry activities. This step's learning protocol stipulates that students must be able to:

- Establish a framework for the conversion between calcium compounds such as $CaCO_3$, CaO, and $Ca(OH)_2$.
- Generalize the three major components of substance research: property, use, and method of production.
- Construct knowledge structures for common chemicals (using the O_2 knowledge structure diagram as an example, as illustrated in **Figure 1**):

Instructional Assessment

The Basic Education Course Standards for Chemistry 2022 place a strong emphasis on the value of a thorough evaluation process that includes evaluations of students' understanding of chemistry, scientific reasoning, scientific practice, and scientific attitudes. By combining teaching, learning, and evaluation, classroom education needs to change from a focus on knowledge delivery to one on the development of critical competencies (Ministry of Education of China, 2022). In protocol-guided instruction, evaluations of pre-class independent student learning, problem-solving, mastery of learning skills and processes, and consolidation of knowledge in and after class are all woven into the instructional assessment process. The protocol-based evaluation is a summative assessment in that it helps to consolidate learning contents and processes. It is a formative assessment since it is integrated into every stage of student learning and guides students through the entire inquiry process. The exercises that follow are part of this lesson's instructional assessment.

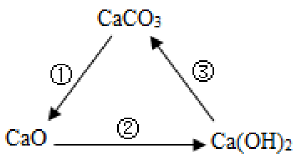
i. In-Class Assessment

Exercise one:

The main component of limestone is $CaCO_3$. Which of the following statements is false? ( )

- *A. $CaCO_3$ is a carbonate.*
- *B. Shells and pearls contain $CaCO_3$.*
- *C. $CaCO_3$ is easily soluble in water.*
- *D. $CaCO_3$ can serve as a calcium supplement.*

Exercise two:



For this triangular diagram of Ca, which of the following statements is false? ( )

- *A. Reaction (1) can be applied to producing quicklime.*
- *B. Reaction (2) can release heat.*
- *C. CaO can serve as a desiccant for certain foods.*
- *D. Reaction (3) must involve CO_2.*

ii. After-Class Assessment

Prepare $CaCO_3$ at home, observe and describe experimental phenomena, and record the process on video.

(*This after-class experiment question is meant to motivate students to put what they have learned in the classroom into practice. An interesting and motivating at-home experiment can help students develop their scientific skills and increase their enthusiasm for learning chemistry while also testing their understanding of the material covered in the course*.)

Reflections from the Teacher

The development of this lesson's learning protocol is an application of the student-centered and teacher-led instruction concept, a basic premise underlying the protocol-guided teaching paradigm. The learning protocol, which closely connects classroom instruction with student life experiences, assists students in achieving learning objectives by leading them through the phases of pre-class preparation, classroom inquiry, summary and reflection, and instructional evaluation. It allows students to participate in a session of experiential, cooperative, and enjoyable classroom learning.

It is essential to highlight the results of the most remarkable activities. According to the learning protocol, students must gather information about the applications of $CaCO_3$ prior to class and present it in class. This not only motivates students to learn independently but also makes them aware that online resources are an essential source of information for chemistry study. If the instructor gave an explicit lecture on the applications of $CaCO_3$, it would be tedious and repetitive. In order to identify $CaCO_3$ in specimens collected at home, students are instructed to design experiments, comment on each other's designs, select the best plan and most reasonable experimental setup, and conduct the experiments in groups based on their prior knowledge of the properties and applications of $CaCO_3$. Through experimentation, they discern the proper method for identifying $CaCO_3$ and even generalize about the methods commonly used to identify members of the carbonate family. The program "Survival in the Wild" functions as an ideal introduction to the preparation of $CaCO_3$ and introduces students to the methods of $CaCO_3$ preparation in the laboratory. Using carbide slag as a basic material to simulate the industrial production of $CaCO_3$ is a valuable lesson in sustainable development for humans. This activity teaches students that chemistry is derived from life, thereby contributing to the advancement of human society (Zou, 2022). This protocol for learning has some limitations. Due to time constraints, the procedure for identifying $CaCO_3$, for instance, only allows students to experiment with a limited number of chemicals. This restriction is inappropriate; students should be permitted to conduct more extensive experiments to determine the optimal identification technique.

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REVIEW

Protocol-Guided Teaching: An Experiment in Chinese Basic Education

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Abstract: *Protocol-guided teaching, a method of classroom instruction reform started by Donglu Middle School in Nanjing of China has developed into a student-centered teaching model in the context of the deepening reform of Chinese basic education. In this model, the teacher plays an essential guiding role, and the main objective is the development of the student's autonomous learning ability. The purpose of this article is to increase interest in and conversations about the protocol-guided teaching model among educational professionals by describing the history of the approach, summarizing its features, and highlighting its implementation tactics.*

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KEY components of school instruction include the instructor, the student, the subject matter, and the instructional strategy. Effective teaching models depend on how these components are arranged. Over the past two decades, protocol-guided teaching has placed a lot of emphasis on the relationships between the key components, and a new viewpoint has been adopted to address the connections between teaching and learning, learning and practice, and student knowledge mastery and competence development. The current study tried to explain the background and characteristics of protocol-guided teaching as well as provide implementation suggestions for this teaching model based on practical explorations of this method in a variety of Chinese primary and secondary schools.

The Background of the Protocol-Guided Teaching Model

Protocol-guided teaching, which originated in Chinese basic education, has been used in a variety of schools in China for over two decades and is regarded as one of the most significant teaching models in Chinese basic education. Kangjing Chen, the head of Nanjing's Donglu Middle School, advocated the use of the "instruction protocol," the first kind of protocol-guided teaching, in 1999. Chen and his teaching staff have made it a success via years of experimentation, reflection, and development under the philosophy of "mutual promotion of teaching and learning in a student-centered classroom" (He &Xu, 2009). Following the introduction of "instruction protocol," other schools attempted to learn from Donglu Middle School's experience.

Instigated by Donglu Middle School's instructional reforms, schools across the nation initiated their own classroom instruction reforms and made ongoing modifications to the "instruction protocol." Consequently, the "instruction protocol" gradually morphed into the "learning protocol," which in some institutions is referred to as "the protocol for students." The transition from "instruction protocol" to "learning protocol" signified a shift from a focus on instructors' instruction to a focus on their guidance on students' autonomous learning, a significant improvement in the new teaching model (Xia & Zhou, 2020).

Protocol-guided teaching is now widely accepted in the educational community as an instruction style in which teachers create student learning protocols prior to the session based on course standards, textbook material, and student learning conditions. Furthermore, these protocols often include learning objectives, materials, methods, and procedures to assist students in engaging in more autonomous learning (Wang, 2020). Teachers do not directly impart knowledge to students in this type of instruction, but rather assist them to inquire and practice independently; the purpose of instruction is to enhance students' capacities and skills through student-centered and teacher-led classroom learning. The learning protocol not only provides students with basic learning materials and teachers with a teaching framework, but it also serves as a guide for student learning by restructuring textbook content with well-designed questions that allow them to explore and solve problems in an organized and sensible manner. Learning protocols that are well designed can have a major positive impact on classroom performance by increasing students' initiative and self-motivation in learning.

The Characteristics of Protocol-Guided Teaching

Equilibrium between Teachers' Instruction and Students' Learning

Teaching and learning have merged into one seamless process as a result of the ongoing advancements made to contemporary educational institutions and the public's enhanced educational viewpoints. An excessive focus on either aspect can lead to an unbalanced condition of the teaching process, which has a detrimental impact on the effectiveness of instruction and student performance. Equilibrium between teacher control and student autonomy can be attained with the aid of protocol-guided instruction. When teachers create learning protocols in advance for their students, they concentrate on creating appropriate learning tasks and approaches while keeping in mind the learning circumstances and characteristics of the students. In order to better meet the needs of the students, they can also modify their teaching procedures while putting the learning protocol into practice.

The protocol-guided teaching model tries to change the traditional didactic teaching style and shift the emphasis of the classroom toward student learning. All of the exercises are made to increase student engagement and guarantee that they actually learn something. By strictly limiting the quantity of teacher speaking, protocol-guided teaching sets itself apart from conventional teaching approaches and turns the students into the main actors in the classroom. As a result, rather than acting as the classroom's controllers, teachers now create the learning environment and serve as facilitators.

Teachers are only permitted to step in and offer guidance when students are having trouble with their learning activities.

A Reconstruction of Learning Substances

The learning protocol can be used as a lesson plan for teachers and as learning materials for students under the protocol-guided teaching paradigm. The fundamental benefit of the learning protocol is how it modifies textbook material. Questions that are pertinent to the course curriculum build on the material from the textbook. Students gain independent inquiry skills as they look for answers to the questions. This represents a radical shift from traditional education. Questions can be challenging and inspirational, which offers good potential for enhancing students' enthusiasm for learning, whereas textbooks are supposed to transfer established human knowledge and experience.

In the past two decades or more, learning protocols have emerged in a variety of forms, and the majority of institutions have developed learning protocols suited to their particular circumstances. Those that have proven effective in course instruction and are well-liked by students have been published and have become prevalent. In the basic education community, the Phoenix Digital Learning Protocol, published by Phoenix Education Publishing, Ltd.; the Digital Learning Protocol, published by Shanghai Educational Publishing House; and the Zhixing Classroom Learning Strategy: Digital Learning Protocol, published by China University of Petroleum Press, are particularly well received.

Well-Organized Learning Procedures and Activities

The explicit prescribing of learning procedures for students is one of the most notable aspects of the learning protocol. A relatively comprehensive learning protocol typically includes student independent study, independent inquiry, exercises, and instructional assessment, despite the fact that institutions' specific learning processes may vary (Zhao, 2022a).

In protocol-guided teaching, Yangzhou Wenjin Middle School, for example, has used a "Four Steps of Guidance" approach. Their school-based learning protocol is designed to guide students through the whole lesson learning process, from pre-class preparation to classroom inquiry, summary and reflection on learning methods, and instructional assessment. The learning protocol suggests a variety of pre-class learning activities for students to help them integrate into learning situations by presenting familiar concepts and the evolution of relevant information. It includes specific planning for class activities to guarantee that classroom inquiry is effective and that the objectives of these activities are met. The following step of summary and reflection assists students in generalizing approaches and researching routes from class activities. The instructional assessment process is interwoven into every step of the student learning process, including evaluations of student autonomous pre-class learning, problem-solving, mastery of learning skills and strategies, and knowledge consolidation after class (Wang, 2022).

The practice of experiential teaching at the Zhenjiang Experimental School makes full use of learning protocols (Xia, 2020). The entire teaching process is divided into a number of learning activities with the use of the school's learning protocols. While teachers simply serve as organizers and "counselors," students complete these tasks independently in groups. Their experiential teaching is founded on the idea that students should acquire content before teachers lecture or demonstrate it to them. Instead, teachers should let students get first-hand experiences through observation and practical application. Students ask questions, consider them, and then debate them as this process progresses. Teachers then provide applicable guidance and suggestions in response to students' individual research. After then, students continue to attempt and experiment in order to identify the norms and laws guiding their practice and discover solutions to the issues they have raised (Xia & Zhou, 2020). This process emphasizes students' agency in the classroom while still providing teachers with full rein in their directing roles. The emphasis of learning protocols-based experiential education is on developing students' capacities for observation, thinking, creativity, innovation, and representation. As a result, it is possible to greatly improve students' all-around competencies.

Shandong 271 Education Group's holistic module learning model incorporates learning protocols. The connotation and structure of the learning protocol have undergone extensive development over the course of years of teaching reform, resulting in the formulation of the holistic module learning protocol, also known as the 271 learning protocol. It is a structured and intelligent learning protocol that includes student learning materials, student learning dynamics, and visual student feedback (Liu, 2022). Consequently, it not only reflects course content but also the students' learning process, which includes its automatic generation, recording, and evaluation. In 271 learning protocols, holistic design, holistic representation, and holistic learning are the three most prominent characteristics. It systematically structures the learning content of the entire module with learning objectives, scenarios, tasks, and evaluation, with an emphasis on the development of students' higher-order reasoning skills.

The knowledge economy sets more stringent requirements on the labor force. It is the obligation of educational practitioners to educate students to be high-quality talents with the ability to learn autonomously and think independently, as well as a sense of social responsibility. Cramming and teacher-dominated classroom instruction can only develop knowledge collectors, not creative talents. As a result, encouraging students' creative thinking is a fundamental factor in the design of 271 learning protocols. Students will automatically develop higher degrees of creativity and a stronger capacity for bearing responsibility as a result of the ongoing effects of such learning procedures, better preparing them for diverse future endeavors (Zhao, 2022a).

In addition, 271 learning protocols place a premium on group study, emphasizing that each student must be a part of an appropriate study group. Cooperative learning within a group is a crucial component of the learning protocol. Each student performs a unique role in their study group based on their individual strengths. Members of the group assist and encourage one another in implementing the protocol. In this process, the teacher serves primarily as a facilitator, never interfering with or disrupting student group activities but providing assistance when necessary. One student from each study group is a member of the specialty study group for each subject. Therefore, each student has the opportunity to join a specialized study group. They engage in subject-based academic research and the planning of the learning protocol; they assist instructors and serve as academic leaders for group members in their assigned courses (Zhao, 2022b).

Supported by Modern Educational Technology

The protocol-guided teaching paradigm emerged alongside the rapid development of information technology and thus has a particular interest in the implementation of educational technology in classroom instruction. In order to generate more effective learning protocols, teachers used educational cloud platforms to seek out educational resources and collaborate on lesson planning. In order to provide precise instruction, teachers use tablets and LED panels to present learning objectives and content, as well as to monitor students' progress. Students can receive assignments from teachers and seek out learning materials using digital devices, as well as use inquiry learning tools provided by educational platforms.

To achieve more tailored training, protocol-guided teaching fully considers digital transformation and the use of big data. Access to high-quality educational resources is a necessary step toward a better teaching strategy, and teachers who are aware of the importance of using high-quality resources can be motivated to maximize learning protocols (Wang, 2022). The digital revolution in education has resulted in the development of digital learning protocols, which are more time-saving and cost-effective than paper-based protocols, allow for real-time communication and feedback, and thus serve to increase teaching efficiency and student-teacher engagement.

Big data stores large volumes of personal information about students, as well as their online interactions and system-generated data. In recent years, there has been an increase in the use of learning analytics and educational data mining in educational communities, as well as a significant shift in the educational technology research paradigm (Zhu & Shen, 2013). When big data is applied to the analysis of students' learning processes, behaviors, and results, more accurate information is provided for decision-making in teaching. Big data-based technologies are used in digital protocol-guided teaching to facilitate student-individualized learning by providing more relevant learning resources and approaches to them based on their unique features and habits, hence improving their learning efficiency and quality.

Implementation Strategies for Protocol-Guided Teaching

Adherence to the Idea of Student-Centered Education

The principle of student-centered education has emerged as a central concept in contemporary education and underpins the majority of teaching paradigms at the basic education level. The protocol-guided teaching approach is based on this educational principle and emphasizes the value of appropriate relationships between learning and teaching, students and instructors, and learning and practice. It focuses on structuring learning experiences with students as the main players.

To encourage students to become more engaged in their learning, a classroom climate that prioritizes learning rather than teaching must be established (Wang, 2022). When teachers' roles change from being classroom lecturers to being planners before class, directors during class, and tutors after class, the transition from passive to active learning can effectively urge students to participate in the course. A more amicable student-teacher relationship can be created as a result. Teachers serve more as learning facilitators, helping and guiding students as needed. Students must take the initiative and be accountable for their own learning. It is possible for teachers and students to enhance their mutual understanding, respect, and trust.

Both practice and acquiring new information are crucial to effective classroom instruction. In a traditional, teacher-centered classroom, student training time is scarce, and teacher lectures prevail. A natural fusion of learning and practice is encouraged by the protocol-guided teaching style. A suitable number of in-class tasks are given to students to help them cement their mastery of the lesson's material based on the assumption that they comprehend it. Opponents of protocol-guided teaching may minimize its effectiveness by associating it with an exercise book because the learning procedure allots a significant amount of time for exercises. That is a severe misinterpretation of this instructional paradigm.

Scientific Design and Use of the Learning Protocol

The instructor controls the classroom in traditional teacher-dominated education models by selecting what to teach, how to teach, and how to evaluate student learning outcomes; at the same time, the student becomes a passive recipient of knowledge and the object of information cramming. A well-crafted learning protocol, on the other hand, is the most important component of the protocol-guided teaching approach, as it governs students' learning activities and teachers' instructional framework. The most essential prerequisite for protocol-guided teaching is protocol-based learning and instruction.

Composing learning protocols requires collective professional knowledge and competence, as well as the participation of all teachers in the school who teach the same discipline. Typically, the creation of learning protocols consists of three steps: in the first step, the learning protocol for a specific lesson is prepared by one teacher; in the second step, all members of the teaching research group of the subject discuss collectively the individual protocol and propose improvements to make it a common protocol for the use of all teachers; and in the third step, all teachers of this discipline further modify the common protocols based on the suggestions made by the teaching research group (Xia & Zhou, 2020).

The Ministry of Education of China has established course requirements for all subjects and learning stages. On the basis of these standards, efforts have been organized to compile textbooks for all subjects. Despite being authoritative and professional, textbooks have limited content and scope. Basic education students must transform the textbook into a comprehensive learning plan that includes learning objectives, content, methods, and activities. The introduction of learning protocols signified a successful shift from textbook-based to learning-plan-based instruction. A learning protocol, unlike a textbook, is created by in-service teachers who take into consideration national course standards, textbook content, and students' learning status, making it more acceptable and beneficial to students.

The core of the protocol-guided teaching methodology is the learning protocol. Teachers at schools that adopt this teaching paradigm must implement instruction using school-designated learning protocols, and students in these schools must adhere to the conditions and guidelines outlined in the protocols when engaging in learning activities. There is no arbitrary teaching or learning methods that go against established learning procedures.

Conclusion

Education has become more demanding as time and society have advanced. The goal of education is no longer only to impart existing knowledge to students but rather to foster autonomous learning abilities and creativity in them. The protocol-guided teaching paradigm has the ability to meet the changing educational requirements. Its application in a wide range of Chinese schools has resulted in learning protocols of various forms but with the same characteristics, and they have proven to be productive in terms of student learning results. We anticipate that through engaging in ongoing practice, summarization, and reflection, more educational practitioners will have a better grasp of the value of this teaching approach and improve its effectiveness in basic education.

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