Imparting 21st Century Skills in the Classroom: Attitude and Perception of Students Towards Chemistry Education

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ABSTRACT

This study investigates the relationship between 21st-century skills and students' attitudes and perceptions toward chemistry education at the secondary level. As education shifts to meet the demands of a technology-driven world, skills such as digital literacy, inventive thinking, effective communication, and collaboration have become essential in science classrooms. The research employed a descriptive survey design, involving 85 Class X students from various schools in Delhi. Data were collected using a structured questionnaire comprising three standardized tools: the Attitude Towards Chemistry Scale, the Perception of Teaching-Learning Process Scale, and the 21st-Century Skills Assessment Tool, which measured digital literacy, inventive thinking, and effective communication. Descriptive statistics were used to determine mean scores and levels of student response, while Pearson correlation analysis was conducted to examine the strength and direction of relationships among the variables. The results revealed that students generally held a positive attitude toward chemistry, with the strongest positive correlations observed between overall 21st-century skills, particularly digital literacy and effective communication, and their attitudes. However, inventive thinking demonstrated a low correlation with attitudes. The findings suggest the need for integrating 21st-century competencies into chemistry instruction through interactive, student-centred, and technology-rich teaching strategies that enhance learning engagement and future readiness.

Keywords: 21st Century Skills, Chemistry Education, Student Attitude, Teaching-Learning Process

INTRODUCTION

Chemistry education the understanding of the natural world, fostering critical thinking, and nurturing scientific literacy among students. As an integral component of science education, chemistry equips learners with essential knowledge and skills to comprehend the composition, structure, properties, and transformations of matter. (Gabel, 1999). Its relevance extends beyond academic realms, influencing various sectors such as healthcare, industry, and environmental conservation. Therefore, the efficacy of chemistry education is paramount in preparing students for the challenges and opportunities of the 21st century. Changes in technology happen almost every day. People need to be able to understand the language of advanced technology proficiently compete in this digital age. As a result, it is the responsibility of the educational system to equip students to meet the global problems of the 21st century.

In today's dynamic educational landscape, the focus has shifted equipping students with the essential skills and competencies needed to thrive in the 21st century (Partnership for 21st Century Skills, 2007). As advancements in technology, globalization, and changes in societal needs reshape the requirements for success, educators are increasingly tasked with integrating 21st-century skills into classroom practices across various disciplines. One such area of focus is chemistry education, which serves as a cornerstone in fostering scientific literacy and critical thinking among students (Schleicher, 2018).

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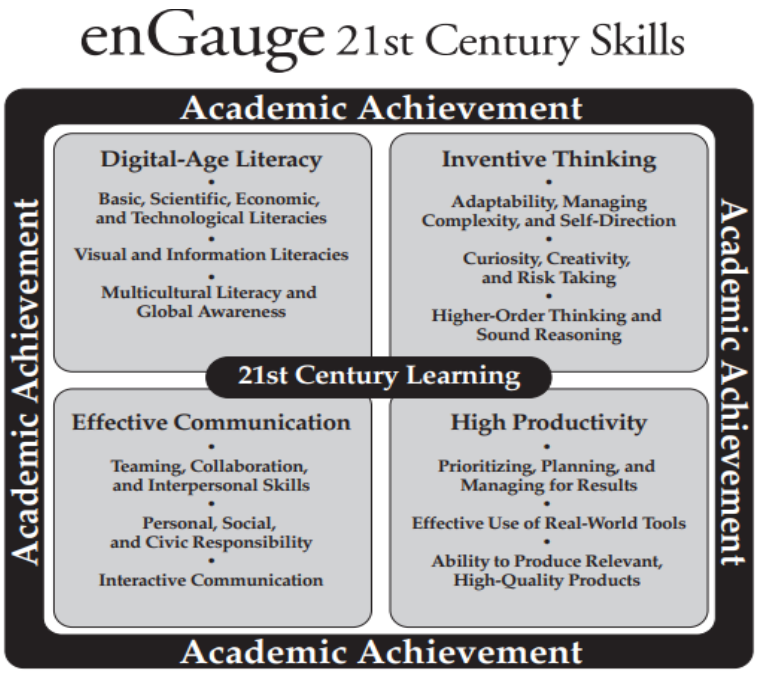
Although the concept of 21st-century skills is not new to the Indian educational system, it is an extension of conventional skills to accommodate new work contexts and technology. This paradigm change highlights how urgent it is for educational institutions to adopt innovative approaches that support students' critical thinking, creativity, collaboration, interpersonal skills, and digital literacy. Teachers may equip students with the skills to face the challenges of the digital era and become flexible, creative individuals ready for success in a world that is changing quickly by placing a high priority on the development of these abilities.

The concept of "21st-century skills" refers to a wide range of competencies, such as digital literacy, critical thinking, creativity, collaboration, and communication (Trilling & Fadel, 2009). These abilities are thought to be necessary for students to succeed in academic and professional activities as well as to successfully navigate a world that is always changing. Many scholars and international organizations have attempted to define and classify 21st-century talents (Yavuz et al., 2020; Zorlu & Zorlu, 2021). Some of these organizations are North Central Regional Educational Laboratory (NCREL), Partnership for 21st Century Skills (P21), Assessment and Teaching of 21st Century Skills Framework (ATSC21), World Economic Forum (WEF), and International Society for Technology in Education (ISTE), and METIRI Group has been actively involved in defining these skills and providing frameworks for their evaluation (Cansoy, 2018). In 2002, Lemke, as part of a project sponsored by the METIRI Group and NCREL, identified 21st-century skills across four clusters: Digital Age Literacy (DAL), High Productivity (HP), Effective Communication (EC), and Information Technology (IT).



Note: (en Gauge, 2003)

However, traditional approaches to teaching chemistry may not always align with the demands of the 21st century. Therefore, understanding the attitudes of students towards chemistry education, particularly in the context of 21st-century skills, becomes paramount for educators and policymakers alike.

Understanding the attitudes of students towards chemistry education and its alignment with the development of 21st-century skills is critical for informing instructional practices and curriculum development initiatives. Students' attitudes towards chemistry education encompass various dimensions, including their interest in the subject, motivation levels, and perceptions of its relevance to their academic and future career pursuits (Kumar & Chacko, 2018; Schwarz & White, 2005).

Moreover, assessing students' perceptions of skill acquisition within the context of chemistry education can provide valuable insights into the effectiveness of current teaching methodologies and the extent to which they facilitate skill development (Gul & Akhtar, 2020). By identifying potential gaps or challenges hindering the

integration of 21st-century skills in chemistry education from the perspective of students, educators can tailor instructional strategies to better meet students' needs and enhance their learning experiences.

Through an exploration of students' attitudes towards chemistry education and their perceived possession of 21st-century skills, this study aims to contribute to the existing body of knowledge on effective teaching practices and skill development in chemistry education. By bridging the gap between students' perceptions and the goals of chemistry education, educators can create more engaging, relevant, and impactful learning environments that prepare students for success in the 21st century and beyond.

LITERATURE REVIEW

21st century skills

21st-century skills (21CSs) include such skills as critical thinking, creativity, collaboration, communication, digital literacy, problem-solving, and adaptability. These are skills and attributes that are often thought to be crucial to enable young people to face tough demands in society, not least the world of work, to see them well prepared to engage in lifelong learning and for lifelong employability (Trilling & Fadel, 2009; Binkley et al., 2012). The Partnership for 21st Century Learning (P21, 2015) organizes these skills into three overlapping domains: learning and innovation skills (4Cs), information and communication technology (ICT) literacy skills, and life and career skills.

In chemistry education, these skills are because of the abstract and complex structure of the subject. In chemistry, students need to link macroscopic explanations to microscopic explanations and to symbolic representations, a process that requires a great deal of conceptual thinking and communication skills (Johnstone, 1991; Dori & Hameiri, 2003). Accordingly, such as inquiry-based learning, collaborative projects, and digital simulations.

(Ambarwati et al., 2021) advocated for the use of virtual labs in teaching chemistry due to the positive role they play in the visualization of abstract concepts in a more student-centred learning environment. These are the environments that promote critical thinking, experimentation, and collaboration and also help in reducing the fear attached to the actual laboratories. Also, (Jack, 2023) highlights the significance of STEM-infused education with 21CSs such as communication, problem-solving, and adaptability in educational curricula.

The scientific inquiry approach embedded in Indonesia's Curriculum 2013, which requires students to observe, experiment, and communicate their results, would enable the development of these skill sets (Setiawan, 2019; Redhana, 2019).

Students' Attitudes Toward Chemistry Education

Student attitudes toward chemistry have a critical role to play in their motivation, involvement, and achievement. As an affective aspect, attitude consists of cognitive beliefs, feelings, and behavioral tendencies toward the subject (Eagly & Chaiken, 1993). The multidimensionality of students' attitudes and the determinants of their attitudes have been analyzed by a number of studies.

(Salta and Tzougraki, 2004) have carried out a pioneering study that indicates that pupils' perceptions of chemistry, mainly with respect to its difficulty, usefulness, and importance, play an important role in their attitudes. But their results showed that girls, more so than boys, tended to think chemistry was challenging and that this was shaped by pervasive stereotypes about gender. In addition to the absence of hands-on practical training, the dominance of theoretical learning may have further influenced a neutral/negative attitude of students, especially in educational settings where laboratory work is scarce or non-existent.

This view is supported by (Gabel, 1999 and Freedman, 1997), who postulate that students' dispositional feelings positively correlate with the connection of chemistry to the real world, like environmental sustainability or health. When students see the importance of chemistry in daily life, their interest and engagement tend to increase.

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Parallel to the results of (Khan and Ali, 2012) investigated the attitude physics of higher secondary school students, targeting their perceptions of physics, teachers, and teaching. Although students acknowledged friendly, approachable, capable instructors, they had reservations about the discipline of chemistry and the "methods of teaching" used. While they recognized its importance in their lives, many students expressed fear about chemistry and were reticent to seek help out of private tuition. To enhance attitudes and outcomes in chemistry education, these insights emphasize the necessity of more engaging, student-centred educational practices as well as the significance of addressing emotional barriers.

Relationship Between 21st-Century Skills and Attitudes Toward Chemistry

The relationship between 21st-century skills (21CSs) and attitudes toward chemistry stands out as an important issue of interest in science education research, and previous research has demonstrated that these competencies contribute to the improvement of learning, the development of positive attitudes, and academic attainment. Fundamental to this perspective is a foundational study by (Pana and Escarlos, 2017) that demonstrated how student attitudes and performance in science were significantly improved when modern, competence-based modes of teaching were applied, suggesting that when pedagogical practices are congruent with 21CSs, learners are more motivated and more successful. Following this framework, (Oral and Erkilic, 2020) explored similar dynamics in physics and found that although 21CSs did not directly boost academic performance, they had a significant impact on students' perceptions and attitudes toward the subject. Since chemistry education entails similar cognitive demands and abstract concepts, is all the more relevant, implying that the benefits observed in physics classes might be successfully translated into chemistry classrooms.

Building upon this, (Tuan Soh et al., 2010), who studied secondary school students, found a strong positive correlation between 21CSs and attitudes physics, as well as a moderate impact on their views of teaching methods. Their findings reinforce the argument that while 21CSs may not overhaul educational practices alone, they do shift students' engagement levels and how they emotionally and cognitively relate to science subjects. Taken together, these studies suggest that promoting 21st Century Skills (21CSs) could act as a lever to enhance the learning environment and motivation for students, especially in more abstract and complex subjects such as chemistry.

(Kan'An, 2018) strengthens this claim further by proving that students with a higher level of 21CSs also perform better in science because of enhanced attitudes and interest, as well as sustained interest and improved attitude. This indicates that the 21CSs not only function as enabling learning outcomes but also serve as motivational drivers, especially when students are confident in their problem-solving, collaboration, and innovation skills. In support of this, (Jack and Uzezi, 2023) noted that students from various secondary schools showed markedly positive attitudes toward 21CSs, suggesting that the skills are regarded as useful and relevant by and for students in many academic and career paths, especially in STEM disciplines.

As an expansion of this understanding, (Hadinugrahaningsiha et al., 2017) examined how embedding the STEAM (Science, Technology, Engineering, Arts and Mathematics) approach into chemistry education could foster 21CSs like collaboration, critical thinking, and ICT literacy. Their findings, too, seemed to align with previous ones regarding the impact of 21CSs on students' attitudes, especially on why students like chemistry, while paying attention to deliberate intervention mechanisms within the chemistry classes offered in the schools. Still, they pointed out the complexities of integrating real-world effective management of teaching materials.

Combined, the works illustrate a story of the evolution and practice of 21st-century integrated skills in science education, particularly chemistry, which improves students' thinking skills and shifts their perspectives and self-engagement towards becoming more proactively prepared for educational and career opportunities. Every single study piece enhances the framework of purpose-driven information construction, which enables the 21st-century science curriculum skills to be embedded into a goal-oriented narrative where learners will be prepared for the future.

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Operational Definition

21st Century Skills

In this study, 21st-century skills are defined as the essential abilities students need to succeed in the digital age. These include digital literacy (e.g., using technology and information effectively), inventive thinking (e.g., creativity, adaptability), effective communication (e.g., collaboration, interpersonal skills), and high productivity (e.g., managing tasks and using tools efficiently). These are the skills students are expected to develop in the context of learning chemistry in the classroom. (NCREL, & Metiri Group, 2003)

Attitude

In this study, attitude refers to students' predisposition or tendency to respond positively or negatively towards chemistry education. It includes three components: cognitive (beliefs), affective (feelings), and behavioral intentions related to learning chemistry (Ajzen, 2005).

Chemistry Education

In this context, chemistry education refers to the formal instruction and learning activities that aim to develop students' understanding of chemical concepts, processes, and practical applications. (Taber, K. S. 2002)

Purpose of the Study

The purpose of this study is to identify the relationship between 21st-century skills and students' attitudes and perceptions toward chemistry.

Research Objectives

In particular, the objectives of this study are to:

To identify the students' attitude towards chemistry education

To identify the students' perception about the teaching-learning process of chemistry.

To identify the students' views about integrating technology by their teacher in the chemistry classroom

To investigate the correlation between students' attitudes towards chemistry education and their proficiency in 21st-century skills.

METHODOLOGY

Research Design

The present study adopted a descriptive survey research design. This design was appropriate for exploring secondary school students' attitudes towards chemistry education, their perceptions of the teaching-learning process, and their proficiency in 21st-century skills. It also enabled the researcher to investigate potential correlations between students' attitudes and their 21st-century skills proficiency.

Population and Sample

The population of the study consisted of secondary school students of class X from various schools in Delhi, including government, private, and public schools. A total of 85 students were selected using stratified random sampling, ensuring representation from each type of school. Because of time constraints and limited access to schools throughout the academic session, a sample of 85 pupils was chosen. Descriptive and correlational studies can use small samples ranging from 30 to 100 are considered acceptable especially when using well-structured

instruments (Fraenkel, Wallen, & Hyun, 2012). In addition, this study functions as a preliminary investigation, offering fundamental knowledge for upcoming extensive research (Creswell & Creswell, 2018).

Instrument for Data Collection

The instrument used for this study was divided into three different parts. Part one elicited information on the students' demographic information, While part two comprised of 12 items focuses on 21st century skills. Part three consists of students' perception towards teaching-learning process of chemistry. The attitude and perception questionnaire used in this study has been developed and modified according to the studies conducted by Jegede (2007) and Robiah et al. (2001). Although the 21st century skills questionnaire was created using the skills mentioned on the enGauge 21st century skills by The Metiri Group's (NCREL).

All items in the questionnaire were measured using a 5-point Likert scale, ranging from 1 = Strongly Disagree 5 = Strongly Agree.

Table 1. Research constructs

S.NO	Construct	No. of Item
1	Attitude towards chemistry	10
2	Digital literacy	04
3	Inventive Thinking	04
4	Effective Communication	04
5	Students perception about teaching-learning process of chemistry	04
6	Students views about integrating technology by their teacher in chemistry classroom	03
	Total	**29**

Thus there are 29 items to represent the six constructs (see Table 1) A five-point Likert scale ranging from strongly disagree (1) to strongly agree (5) was employed in the questionnaires to allow respondents to indicate their response to each item.

Jackson (2006) defines validity as a tool that measures the extent of what the study should measure. We validated the instrument through expert review for content validity and piloted it with a small group of students to ensure reliability and clarity. The internal consistency of the scale was confirmed using Cronbach's alpha (see Table 2).

Table 2. Scale reliability using Cronbach's alpha coefficient for the construct

S.NO	Construct	Cronbach's Alpha
1	Attitude towards chemistry	.933
2	Digital literacy	.929
3	Inventive Thinking	.85
4	Effective Communication	.915
5	Students perception about teaching-learning process of chemistry	.745

6	Students views about integrating technology by their teacher in chemistry classroom	.850
	Total construct	**29**

Data Collection Procedure

Data were collected in person, with prior permission obtained from school authorities. Participants were informed about the purpose of the study and assured of confidentiality. Participation was voluntary, and responses were anonymized.

Data Analysis Techniques

The collected data were analyzed using SPSS software. The following statistical techniques were employed:

We used descriptive statistics (mean and standard deviation) to summarize students' attitudes, perceptions, and 21st-century skill levels.

The Pearson's Correlation coefficient is used to investigate the relationship between students' attitudes towards chemistry education and their proficiency in 21st-century skills.

FINDINGS

Objective 1: To identify the students' attitudes toward chemistry education.

Table 3. Students' attitude towards chemistry

Criteria	Mean	Std. Deviation	interpretation
I believe that I know and understand chemistry.	3.88	1.293	High
Knowledge of chemistry is useful to me and related to my life.	3.87	1.331	High
I believe that understanding chemistry concepts is important for my future career or academic goals.	4.11	1.332	High
I like chemistry more than other course subjects.	3.36	1.560	Medium
The use of practical experiments and demonstrations makes chemistry lessons more effective and interesting	4.21	1.525	High
My chemistry textbook is not found to be interesting	3.46	1.512	Medium
Only very brilliant students should study chemistry.	3.51	1.550	Medium
Personally I believe that chemistry is complex and difficult subject.	3.16	1.583	Medium
The concepts, theories and formulas of chemistry are too difficult to understand as compared to other science subjects.	3.26	1.601	Medium
Doing chemistry practical is wastage of time.	3.26	1.593	Medium
Overall Mean	**3.60**		**High**

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From Table 3, the overall mean score of 3.60, interpreted as high, indicates that students generally hold a positive attitude toward chemistry education. They strongly agreed that understanding chemistry is essential for their academic and career goals (mean = 4.11) and that practical experiments and demonstrations enhance lesson effectiveness and interest (mean = 4.21), suggesting that hands-on learning their favorable attitudes. Students also recognized the relevance of chemistry in their lives (mean = 3.87) and felt confident in their understanding of the subject (mean = 3.88), both interpreted as high, showing that they chemistry meaningful and valuable. However, several aspects received only a medium interpretation, indicating areas of mixed or less positive perception. For example, students were neutral about liking chemistry more than other subjects (mean = 3.36) and found the textbook less engaging (mean = 3.46). Some students perceived chemistry as too complex or difficult (means ranging from 3.16 to 3.51), particularly in relation to concepts, theories, and formulas, as well as in comparison to other science subjects. The idea that chemistry is only for brilliant students and that practical work is a waste of time also reflected moderate agreement, which points to possible barriers to engagement or confidence in learning. In summary, while students value chemistry and recognize its importance and relevance, the perception of difficulty, lack of interest in textbooks, and complexity of the subject present areas that could be improved through more engaging, accessible, and student-friendly approaches.

Objective 2: To identify the students' perception about the teaching-learning process of chemistry.

Table 4. Students' perceptions towards the teaching and learning of physics

Criteria	Mean	Std. Deviation	Interpretation
The variety of instructional methods used by teachers (e.g., lectures, hands-on activities, demonstrations) enhances my understanding in chemistry.	3.78	1.217	High
My chemistry teacher always encourages me to solve chemistry problems by finding information from the Internet	4.09	1.259	High
My chemistry teacher always encourages me to use the knowledge of chemistry to produce an idea or product that can bring benefits to the community and country.	3.67	1.441	High
My chemistry teachers did not show the techniques to handle the chemistry laboratory equipment.	3.38	1.569	Medium
Overall mean	**3.73**		**High**

From Table 4, the data on students' perception of the teaching-learning process of chemistry reveals an overall positive outlook, with a mean score of 3.73 considered high. Students highly agreed that the use of various instructional methods such as lectures, hands-on activities, and demonstrations enhances their understanding of chemistry (mean = 3.78), highlighting the effectiveness of diverse teaching strategies. The highest mean score (4.09) was recorded for the item stating that teachers encourage students to solve problems using internet resources, reflecting a strong emphasis on digital literacy and self-directed learning. Additionally, students showed a positive perception (mean = 3.67) towards their teachers motivating them to apply chemistry knowledge to develop ideas or products beneficial to society, indicating an integration of real-world applications in learning. However, the mean score of 3.38 for the statement about the lack of demonstration in handling laboratory equipment was interpreted as medium, suggesting that practical instruction in laboratory techniques is an area that requires further attention and improvement. Overall, the findings suggest that while instructional and digital teaching strategies are well-received, there is a need to strengthen the hands-on laboratory component of chemistry education.

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Objective 3: To identify the students' views about their teacher's integration of technology in the chemistry classroom.

Table 5. Students views about integrating technology by their teacher in chemistry classroom

Criteria	Mean	Std. Deviation	Interpretation
My chemistry teacher effectively utilize technology to enhance the clarity of explanations and demonstrations during class.	4.17	1.174	High
How comfortable do you feel approaching your chemistry teacher for assistance or clarification regarding technology-related issues in class?	4.13	1.039	High
My chemistry teacher use technology to provide feedback on our assignments, quizzes, or projects.	4.23	1.136	High
Overall mean	**4.17**		High

From Table 5, the data on students' views about integrating technology by their chemistry teachers indicates a strongly positive perception, with an overall mean score of 4.17, interpreted as "high." Students agreed that their teachers effectively utilize technology to clarify explanations and demonstrations in class (mean = 4.17), suggesting that digital tools are enhancing understanding and engagement. Additionally, students reported feeling comfortable approaching their teachers for help with technology-related issues (mean = 4.13), indicating a supportive and approachable learning environment. The highest mean score (4.23) was observed in relation to teachers using technology to provide feedback on assessments, reflecting active and efficient use of digital tools to improve student learning and communication. Overall, these findings suggest that chemistry teachers are successfully integrating technology in ways that support instruction, feedback, and student-teacher interaction, contributing positively to the teaching-learning experience in the classroom.

Objective 4 between students' attitudes and perceptions towards chemistry education and their proficiency in 21st-century skills.

Relationship of 21st century skills on students' attitude towards Chemistry

Table 6. Relationship of 21st century skills on students' attitude towards chemistry

Criteria	Pearson correlation coefficient	Level of significance
The relationship of digital age literacy to students' perception on teaching and learning Chemistry.	0.22	Low
The relationship of inventive thinking skills on students' perception of teaching and learning Chemistry.	0.31	Medium
The relationship of effective communication skills on students' attitude towards Chemistry.	0.85	High
The relationship of 21st century skills to students' attitude towards Chemistry	0.89	High

** Significant at the 0.01 level

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Table 6, reveals important insights into the relationship between 21st-century skills and students' attitudes and perceptions toward chemistry education. A low positive correlation (r = 0.22) was found between digital age literacy and students' perception of teaching and learning chemistry, indicating a slight but limited influence. Inventive thinking showed a moderate correlation (r = 0.31), suggesting that students who exhibit stronger creativity and problem-solving skills tend to view chemistry instruction more favorably. In contrast, effective communication skills demonstrated a strong positive correlation (r = 0.85) with students' attitudes toward chemistry, implying that students who are better at expressing and exchanging ideas are much more likely to have a positive disposition toward the subject. he overall 21st-century skills score showed a very strong correlation (r = 0.89) with students' attitudes, highlighting the significant role these competencies play in enhancing student engagement, motivation, and interest in chemistry. Collectively, these findings suggest that while individual skills such as digital literacy and inventive thinking have some impact, comprehensive development of 21st-century skills, especially communication, plays a key role in shaping students' positive attitudes toward learning chemistry.

4.2 Relationship of 21st-Century Skills to Students' Perceptions of Teaching and Learning Chemistry

Table 7. Relationship of 21st century skills on students' perceptions teaching and learning chemistry

Criteria	Pearson correlation coefficient	Level of significance
The relationship of digital age literacy on students' attitude towards Chemistry	0.84	High
The relationship of inventive thinking skills on students' attitude towards Chemistry.	0.08	Low
The relationship of effective communication skills on students' attitude towards Chemistry	0.77	High
The relationship of 21st century skills on students' perception teaching and learning Chemistry.	0.58	High

** Significant at the 0.01 level

Table 7 indicates Pearson correlation coefficients to explore the relationship between various 21st-century skill components and students' attitudes or perceptions toward chemistry and its teaching-learning process. The results show a high positive correlation (r = 0.84) between digital age literacy and students' attitude chemistry, suggesting that students with stronger digital skills are much more likely to have favorable attitudes toward the subject. Similarly, effective communication skills also show a high correlation (r = 0.77) with attitude, indicating that students who tend to feel more confident and engaged in chemistry learning. In contrast, inventive thinking skills display a low correlation (r = 0.08) with students' attitudes, implying that creativity and problem-solving, on their own, may not significantly influence how students feel about chemistry. Finally, the overall relationship between 21st-century skills and students' perception of the teaching-learning process in chemistry shows a high correlation (r = 0.58), suggesting that students with stronger 21st-century skills tend to view the instructional methods and classroom environment more positively. Overall, the data points out the vitality of digital literacy and communication skills in fostering positive student attitudes toward chemistry while highlighting the comparatively limited role of inventive thinking in this context.

DISCUSSION

This study's findings show significant evidence of the strong correlation between students' 21st-century skills and their attitudes and perceptions regarding chemistry education. The high overall mean in students' attitudes about chemistry demonstrates that students understand the subject's importance for academic advancement and

employment in the future, particularly when practical and real-world connections are emphasized. These results are consistent with the findings of Salta and Tzougraki (2004), who emphasized that students' perceptions are shaped by perceived relevance, difficulty, and the effectiveness of instructional approaches. Similarly, Gabel (1999) and Freedman (1997) argued that chemistry teaching becomes more when students can apply the subject matter to real-life circumstances, such as environmental or health issues.

The findings also show that students' perceptions of the teaching-learning process were very favorable when it included various teaching strategies, digital resources, and chemistry applications to social and community concerns. This supports Ambarwati et al. (2021), who promoted virtual labs and student-centred environments as ways to enhance visualization and reduce anxiety. As suggested by Redhana (2019) and supported by the enGauge framework (Lemke, 2002), which highlighted digital age literacy as an essential skill for modern education, the high level of student agreement with statements regarding the use of technology by their chemistry teachers demonstrates the successful integration of digital literacy into teaching practices.

Furthermore, this study's correlation analyses show a substantial relationship between students' positive attitudes toward chemistry and digital age literacy and effective communication. This is in line with research by Kan'An (2018) and Jack and Uzezi (2023), who discovered that students who possessed stronger 21st-century skills were not only more involved but also outperformed in the classroom. It's to note that, despite its importance, inventive thinking only weakly correlated with students' attitudes, suggesting that creativity and problem-solving alone may not be sufficient to influence students' emotional and motivational engagement unless reinforced by communication, collaboration, and supportive instructional strategies.

The strong correlation ($r = 0.89$) between students' attitudes toward chemistry and their overall 21st-century skills demonstrates the overall impact of these competencies on determining students' motivation, engagement, and interest. These results support those of Pana and Escarlos (2017), who suggested that skill-based teaching approaches greatly improve attitudes and academic performance. Similarly, the moderate to strong correlation between these abilities and students' opinions of the teaching-learning process provides support to the argument that students learn more effectively and meaningfully in classrooms that are aligned with 21CSs.

Furthermore, this study supports the findings of Tuan Soh et al. (2010), who revealed similar trends in physics education, showing that the use of 21CSs improves student attitudes, which results in moderate improvements in how teaching methods are perceived. According to the persistent pattern shown in several research studies, improving students' cognitive and emotional engagement in chemistry instruction requires integrating communication, digital literacy, collaboration, and real-world problem-solving**.**

CONCLUSION

This study aims to examine the relationship between 21st-century skills and students' attitudes and perspectives about chemistry education at the secondary level. The findings clearly show that students generally have a positive attitude towards chemistry, particularly when taught through practical, engaging, and real-life-related approaches. Students praised the use of technology and different methods for instruction by their teachers, emphasizing the importance of integrating current techniques and approaches into the teaching-learning process. Among the numerous 21st-century skills examined, effective communication and digital-age literacy were found to have the most positive correlation with students' attitude toward chemistry. The finding indicates how important these characteristics are in improving students' motivation, knowledge, and engagement. While innovative thinking was less highly connected, it nevertheless helped to affect the views of students, particularly when combined with other skill sets. Overall, pupils who showed higher competency in 21st-century skills were more likely to assess chemistry education positively and exhibit a more favorable attitude toward the subject. The findings highlight the importance of a transformation in teaching methodologies to emphasize cooperation, communication, creativity, and the integration of technology. Chemistry educators should prioritize these competencies not only to improve academic achievements but also to develop a learning environment that is relevant, inclusive, and future-oriented. As the world continues to evolve with rapid technological advancements and global challenges, equipping students with 21st-century skills within the context of chemistry education is essential for preparing them to become competent, confident, and adaptable individuals in both academic and professional spheres.

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