ISSN:3007-9659 DOI: https://doi.org/10.70114/ahmer.2025.2.1.P115

Development and Validation of Self-Assessment Instrument in Science for 21st Century Skills of Junior High School Students

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Abstract. In today's challenging and competitive world, it is crucial that individuals must possess 21st century skills. This study aimed to develop and validate a self-assessment instrument for 21st century skills in science of junior high school students. A mixed-method research design was employed in this study. The perceptions of the students and teachers about the 21st century skills were gathered and analyzed using the thematic analysis, which were then utilized as the basis for generating the indicators for the pre-identified variables of 21st century skills' framework. The developed self-assessment instrument was validated by experts and pilot-tested among junior high school students for reliability testing. The instrument underwent a series of revision and was refined through Confirmatory Factor Analysis that showed robustness with factor loadings of greater than 0.50 in two clusters, Learning and Innovation Skills, and Collaborative and Digital Literacy Skills.The revised instrument which was refined through Confirmatory Factor Analysis has shown robustness, with two clusters, Learning and Innovation Skills and Collaborative and Digital Literacy Skills, having factor loadings greater than 0.50. The Learning and Innovation Skills cluster retained 13 indicators, while the Collaborative and Digital Literacy Skills cluster retained 7 indicators. The instrument's reliability analysis shows acceptable internal consistency, with a Cronbach's alpha of 0.76, exceeding the commonly accepted threshold.

Keywords: learning and innovation skills; collaborative and digital literacy skills.

1. Introduction

The role that science and technology play in the development of a nation and the exponential growth of technology in the 21st century make them indispensable in today's world. In an increasingly interconnected and rapidly evolving world, the importance of equipping individuals with 21st-century skills cannot be overstated. These skills are essential for success in both personal and professional realms. To adapt to these changes and opportunities, individuals must develop the necessary skills, which range from basic skills such as literacy, numeracy, and digital technology to vocational or technical skills, entrepreneurial and transversal skills such as foreign languages, personal development, and learning to learn. All of these skills are required to ensure an individual's well-being while also contributing to society, productivity, and economic development [1,2].

In order to match educational procedures with the demands of a society that is changing rapidly, it is imperative that experts develop a self-assessment instrument for 21st-century skills. The competences needed in each discipline can be observed and assessed from a variety of perspectives, such as technological, pedagogical, contextual, and humanistic ones, using integral educational framework models. It is the responsibility of educators to determine whether the competences and teaching methodologies used now are adequate to meet the abilities that students will need to enter the workforce in the twenty-first century [3]. The 21st-century skills framework places a strong emphasis on vital skills including digital literacy, problem-solving, critical thinking, creativity, and teamwork [4].

The development of self-assessment tool in this study involved careful selection of the 21st century skills from different frameworks. There are different international organizations which have their own 21st century skills framework such as Partnership for 21st century skills (P21), En Gauge, Assessment and Teaching of 21st Century Skills (ATCS), and many others. This study utilized the conceptualization of 21st century skills by P21 and En Gauge since the skills laid out in their

ISSN:3007-9659 DOI: https://doi.org/10.70114/ahmer.2025.2.1.P115
framework are related to education. The skills that were incorporated in the development of self-assessment instrument are the skills from two frameworks of international organizations. The first set of 21st century skills is the Learning and Innovation Skills which are categorized into: critical thinking; creativity; communication; and collaboration. These skills are the frameworks from P21 organization [5]. The second set of skills is from En Gauge, the Digital-age Literacy which involves: technology literacy; information literacy; and global literacy ([6]. These 21st century skills are selected since they are mostly related to the skills measured in education sector.

Hence, this study developed an assessment tool for 21st century skills for junior high school students in DepEd of Davao de Oro. The instrument is named SAI-21-CSS which stands for Self-assessment Instrument for 21st Century Skills in Science. The objectives of this research are to develop and validate a 21st century skills self-assessment instrument in science for junior high school students. The author grasped the vast scope of 21st century skills hence, this survey tool is not an assessment of all the 21st century skills.

2. Literature Review

The term "21st-century skills" describes a broad range of aptitudes, cognizance, and mindsets required for people to prosper in the complicated, fast-paced, and globally interconnected world of today. People in today's information and technology-driven society are expected to possess advanced abilities like critical thinking, decision-making, communication, creativity, and problem-solving, rather than merely relying on content-oriented instruction and talent development procedures [7]. The "4Cs"—Critical thinking, communication, collaboration, and creativity—are highlighted in the "Framework for 21st Century Learning" put forth by the US-based Partnership for 21st Century Learning (P21). Teachers throughout are in need of implementing learning and innovative skills, but little is known about how to do so successfully. Successfully implementing these skills in schools assists in the development of an altruistic society for people, communities, and the nation in general [8].

Students must acquire the critical thinking, problem-solving, communication, and teamwork skills necessary for success in the modern world in addition to the fundamental knowledge and comprehension of academic subjects. Students' engagement in the learning process can be increased when a school builds on 21st century knowledge and skills by integrating P21 framework with the required support systems, including curriculum and instruction, assessments, standards, professional development, and learning environments. After graduation, they will be more equipped to prosper in the current global economy [5].

Digital literacy encompasses not only the ability to use digital technologies effectively, but also the capacity to critically engage with the vast array of information, communication, and collaboration opportunities presented by the digital landscape [9]. As the world becomes increasingly interconnected, the ability to access, interpret, and utilize digital resources in meaningful ways has become indispensable for individuals seeking to succeed academically, professionally, and as engaged citizens. The COVID-19 pandemic has highlighted the essential requirement for digital literacy, especially as educational institutions swiftly shifted to online learning. This emphasized the significance of digital skills for students at every stage of their education [10].

Students who are not proficient in digital skills and knowledge find it difficult to adjust to technology-enabled learning. As a result, they either quit the educational system or are unable to advance in their studies. Increasing graduates' digital literacy will help reduce the high attrition rates in online education and better prepare them for the workforce [11]. People who are proficient in digital skills typically outperform those who are not in the workplace in terms of productivity. Businesses are also conscious of the disconnect between current and required digital competencies. In order to guarantee that their workforce possesses the necessary digital competencies for the

ISSN:3007-9659 DOI: https://doi.org/10.70114/ahmer.2025.2.1.P115
increasingly digitalized future, numerous employers are arranging digital workshops and training [12,13].

3. Methods

3.1 Research Design

This study employed mixed method research design particularly sequential exploratory design. The qualitative phase of the study involved data gathering of the perceptions of teachers and students regarding 21st century skills. Data collected was analyzed through thematic analysis. The data collected in qualitative phase were used to craft item indicators for the self-assessment instrument. The combination of qualitative and quantitative techniques allowed the researcher to gather rich data in completing the development of 21st century skills self-assessment instrument.

3.2 Population and Sample

The study took place in public schools of District 1, Davao de Oro. In qualitative phase, there were 14 students and 14 teachers involved in in-depth interview and focused group discussion. For pilot testing, the self-assessment instrument was administered in 280 junior high school students. To ensure that each subgroup is fairly represented in the sample, stratification helps to minimize the possibility of sampling bias. Hence, stratified random sampling is utilized in this study.

3.3 Data Gathering Instruments

This study developed and validated a researcher-made questionnaire named as self-assessment instrument for 21st century skills in science (SAI-21-CSS). This instrument was validated by experts before it was subjected to pilot testing. It was then subjected for reliability testing. Additionally, the researcher-made instrument utilized 7-point Likert Scale. The five ordered response levels are often practiced, but many psychometricians suggest using 7 or 9 level. The reason for this is based on empirical study conducted by Dawes [14] that a 7-point scale may produce slightly higher mean scores relative to the highest possible attainable score. The 7-point Likert Scale that was utilized in the instrument, was adapted and modified from Jamora [15] as cited by Pimentel [16].

3.4 Data Gathering Procedure

The researcher sought permission to the Department of Education Provincial Office in Davao de Oro. A letter for permission was submitted to the Schools Division Superintendent (SDS) for the approval and authorization to proceed for the conduct of the study. The qualitative phase of the study was conducted through in-depth interviews (IDI) and focused-group discussion (FGD) with the students and teachers to gather their perceptions about 21st century skills. The data collected were subjected to thematic analysis and were used to craft the items for the self-assessment instrument.

3.5 Analysis of Data

Thematic analysis was used for qualitative data. For reliability testing, the following analyses were conducted: Cronbach's Alpha Coefficient; Standardized Alpha; Average inter-item Correlation. Principal Component Analysis was used for construct validity. In order to test the suitability of data for factor analysis, the following tests were performed: Scree Plot and Eigen Values Analysis; Bartlett's Test of Sphericity; and Kaiser-Meyer-Olkin (KMO) Measure of sampling adequacy. Finally, confirmatory factor analysis (CFA) was used in structural analysis.

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4. Results and Discussion

4.1 Perspectives of Teachers and Students for 21st Century Skills

The two major factors and the seven sub-factors of 21st century skills for this instrument had been pre-identified based on related literature and these are: Learning and Innovation Skills (Critical thinking and problem solving, Creativity and innovation, Communication and Collaboration); and Digital Literacy Skills (Scientific and technology literacies, Visual and information literacies, and Global awareness). The following results are the perspectives of students and teachers about 21st century skills.

4.1.1. Learning and Innovation Skills

a. Problem-solving skills and critical thinking skills. Teachers were asked about their perspectives about critical thinking and problem-solving skills of the students especially during their science lessons. Students were also asked about their experiences and their perspectives whether they possess critical thinking and problem-solving skills. For instance, teachers were asked a question, “Can you describe specific actions or behaviors of your students in classroom that demonstrate active engagement in critical thinking and problem-solving during classroom activities?”. Most teachers shared that many students ask questions when they are in doubt. One teacher participant shared,

“Students are fond of asking questions about the concepts to satisfy
their curiosity.”

The students on the other hand were also asked the same question and shared their perspectives when asked a question, ““Can you describe your specific actions or behaviors in classroom that demonstrate active engagement in critical thinking and problem-solving during classroom activities?”. Some student participants shared that they listen to instructions carefully to understand well. Specifically, a participant stated,

“I take time to analyze problems and refer to prior knowledge.”

This statement was also concurred by other student participants. They shared that they usually connect their prior knowledge to the current concepts they are learning in the classroom. The ability to think critically is essential for analyzing problems and coming up with solutions. Critical thinkers are not just knowledgeable about the solution. Based on the knowledge and data gleaned from an issue, they will attempt to generate potential solutions [17]

b. Creativity and innovation skills. When teachers were asked, “Can you give me an example of a time when a student came up with a unique solution to a problem or presented a new idea that surprised you?”, some of them shared that students are very creative in customizing materials for their projects. Student participants were asked, “What are some of the key indicators that you are truly engaged in creativity and innovation, rather than just following instructions or replicating existing ideas?”. Some of them shared that they develop unique concepts. One participant stated,

“I explore and experiment new ideas beyond what our task requirements”

It is crucial to cultivate innovation in the workplace at this time. In order to form and mature creativity, learning must be pursued. Being able to be creative is crucial for students to have after they graduate and are working on ever-changing projects. Additionally, creativity is critical to the success of complex problem-solving activities. Creativity contributes to the stimulation of new ideas through thorough investigation and thought [18].

c. Communication. When students were asked with a question: “What are some specific actions you take when you are actively trying to communicate your ideas effectively to others?”, Some of them answered: "We deliver ideas clearly to the teacher or classmates." Some students show timidity when asking questions directly to the teacher as one participant shared, “We struggle to explain our ideas”. Teachers were also asked the same question and shared something about communication skills of the students. Some of them shared,

“Some students show active participation and share ideas about

ISSN:3007-9659 DOI: https://doi.org/10.70114/ahmer.2025.2.1.P115

the lessons"; "They organize ideas logically".

Communication is the exchange of messages across various media. One important discovery was that communication is a skill that opens up other 21st century skills. Communication skills are a prerequisite for the more complex and advanced soft skills of risk-taking, problem-solving, stress management, and critical thinking. Effective communication is a result of language's enormous influence on the growth of positive human relationships. The actual goal of efficient communication is to successfully transfer information from one individual to another [8].

d. Collaboration. Students shared how they collaborated with their classmates during classroom activities. When they were asked with a question, "Describe specific actions or behaviors you observe in yourself that demonstrate your active engagement in collaboration during classroom activities", one participant shared, "Actively participating in group meetings and sharing my thoughts.". Another participant shared. Teachers were also asked how their students demonstrate collaboration skills in the classroom with the same question, and one teacher stated,

"Leaders in the group usually assigns task based on member's
strength to ensure that all members are collaborating"

Increasing the efficacy of teaching secondary students' collaborative skills is the subject of several studies. Working together is a key component of other learning and creative abilities among students. Collaboration is the dedication to proficiently working in groups with others. Additionally, collaborators have an impact on groups through goal-setting, workload and idea sharing, facilitation and contribution, power and decision-sharing, and constructive conflict [19].

4.1.2. Digital-age Literacy

a. Scientific and technology literacies. When students were asked about the question, "Do you think you are equipped with technological skills to understand information in digital age?", answers were mixed as some of them exhibited knowledge in technology while there are still some who still struggle in using technology. One student shared, "Technology is frequently incorporated into our discussions with classmates especially when we have reporting.", one also shared, "I sometimes struggle when having online class". On the other hand, when teachers were asked about the question, "How do teachers perceive the development of digital-age literacy skills, specifically scientific and technological literacies of selected junior high school students?". One teacher said,

"They use digital tools. Students often surpass teachers in
technological skills"

The educational process is enhanced and students show interest when technology is used for teaching purposes. Making e-learning platforms compatible with modern smart devices, such smartphones and tablets, has been crucial to the accessibility and quick adoption of digital learning. One of the well-known causes of learning crises was mentioned in the same study. The inadequate quality of training is one important contributing element. Teachers are often poorly trained and lack subject-matter competence [20].

b. Visual and information literacies. Students were asked the question, "In terms of visual and information literacies, how do you see your ability to identify bias and misinformation in online content?", one student shared, "Identifying bias and misinformation is critical in the digital age. I make sure information is relevant", another student said, "I do my best to understand the topic and to enhance my understanding, I research online to gather more information about the topic". When it comes to students' ability to incorporate technology to better understand scientific concepts, one teacher shared,

"Students utilize animations, videos, interactive tools to better
understand scientific concepts."

Students that possess digital literacy are able to incorporate new media into their education, including animations, simulations, videos, and other interactive materials. Digital literacy is the capacity to access, assess, and process information in a variety of digital formats using information and communication technologies [21].

ISSN:3007-9659 DOI: https://doi.org/10.70114/ahmer.2025.2.1.P115

c. Global awareness. Students were also interviewed about global issues. Specifically, they were asked whether they have researched global issues about science topics. Some of them answered, ""we use internet to research assignments and make sure to access reliable websites.", also one student said, "If there are global issues, I research online about it and I connect it to the knowledge I gained in the classroom." These questions were also asked to teachers and one stated,

"Students have limited access to internet, hence, the inability to
be active or have limited skills in terms of global issues"

Students are motivated when they are given the required resources, such as electricity, internet bundles, and personal computers or smartphones, as they are considered the primary drivers of e-learning [22]. He demonstrates how the global crisis emphasizes the importance of technological proficiency in addressing it and promoting education [23].

4.1.3. Sample of Items Crafted from Interviews

Based on the data gathered from qualitative phase, there are 8 items crafted per sub-variable. Hence, a total of 56 items crafted for the self-assessment instrument. Table 2 presents the sample of items that were crafted during interviews of students and teachers regarding their perspectives on 21st century skills. For instance, in Critical Thinking and Problem-solving Skills, there were 8 items crafted for the instrument. Table 1 only shows sample items CTPS 1-4 and sample items CI 1-4.

Table 1. Sample Items Crafted in Qualitative Phase

Factors	Sub-factors	Crafted Items
Learning and Innovation	Critical Thinking and Problem Solving	I break down complex problems into simplified components.
		I make sure to ask questions when in doubt.
		I analyze the problems first and connect them to my prior knowledge.
		I believe accurate answers are derived through personal experiences in laboratory experiments and hands-on activities.
	Creativity and Innovation	I explore new ideas and am willing to take risks.
		I contribute original ideas and integrate feedback from peers.
		I innovate by utilizing domestic or recycled items in doing science projects.
		I love creating science models by using practical materials.

4.2 Reliability and Validity Coefficients of Self-assessment Instrument

The succeeding tables provide the results of the reliability and validity coefficients of the self-assessment instrument crafted based from the qualitative phase. Table 2 shows the results of the reliability test of the self-assessment instrument.

Table 2. Reliability Test

Standardized Cronbach's Alpha	Cronbach's Alpha	Average Inter-Item Correlation	Remark
0.64	0.76	0.031	Consistent

Note: Cronbach's Alpha >=0.7

The reliability analysis of the instrument demonstrates acceptable internal consistency, with a Cronbach's alpha of 0.76, exceeding the commonly accepted threshold of 0.70. This value was achieved by reversing negatively correlated items, such as those in the Collaboration (COLL), Scientific & Technology Literacy (STL), Visual & Information Literacy (VIL), and Global

ISSN:3007-9659 DOI: https://doi.org/10.70114/ahmer.2025.2.1.P115
Awareness (GA) domains, to align them with the scale's direction. The standardized alpha of 0.64 indicates some variability in item scales, while the low average inter-item correlation (0.031) suggests that the items measure distinct aspects of the construct.

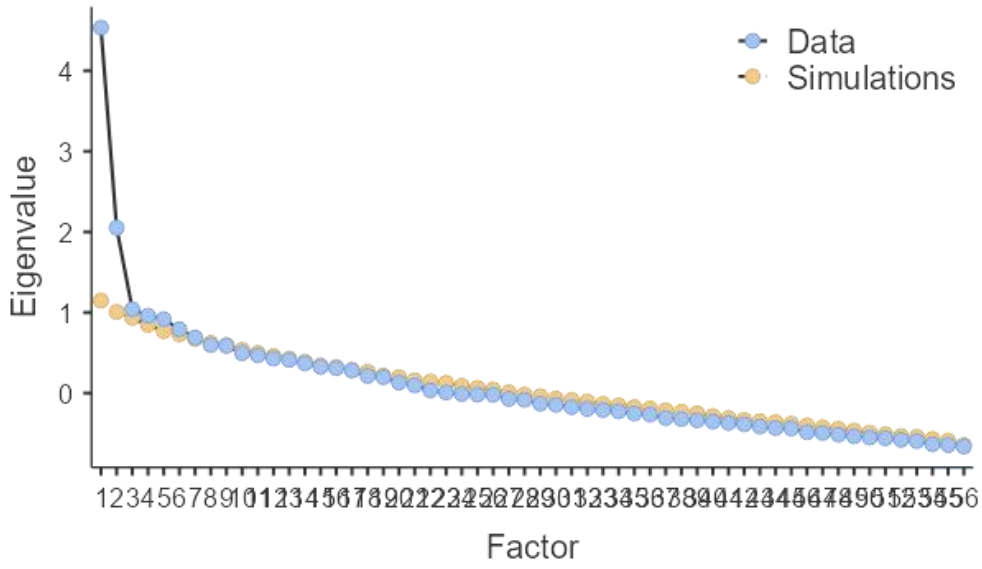

Figure. 1 Scree Plot

The scree plot shown in Figure 1 illustrates the eigenvalues associated with the factors extracted during the Principal Component Analysis (PCA). The plot demonstrates a sharp decline in eigenvalues, followed by a leveling off, which is a typical pattern used to determine the number of significant factors. Based on the "elbow" of the curve, three factors were identified as significant. These factors have eigenvalues greater than 1 and collectively explain 63.01% of the total variance, indicating that they capture a meaningful proportion of the variability in the data. In contrast, the subsequent factors have eigenvalues closer to or below 1, suggesting that they contribute less to the overall variance and likely represent noise or redundant information.

Table 3. Bartlett's test of Sphericity

χ^2	df	p-value	Remark
3064	1540	<.001	Significant

Table 3 displays the results of Bartlett's Test of Sphericity, which yielded a χ^2 value of 3064 with 1540 degrees of freedom and a p-value of less than 0.001. This indicates that the correlations between the variables are sufficiently large for factor analysis.

Table 4. KMO Measure of Sampling Adequacy

	MSA	Remark
Overall	0.649	Adequate

Table 4 presents the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy, which has an overall value of 0.649. This value exceeds the minimum threshold of 0.50, suggesting that the sample is adequate for conducting PCA. The combination of the scree plot, Bartlett's test, and KMO measure confirms that the data is suitable for factor analysis and supports the decision to retain three significant factors. This underlying structure provides a robust foundation for interpreting and grouping the skill categories further.

To further investigate the relationship of this skill categories, the correlation between the skill categories and the factor loadings are summarized in Figure 2.

ISSN:3007-9659 DOI: https://doi.org/10.70114/ahmer.2025.2.1.P115

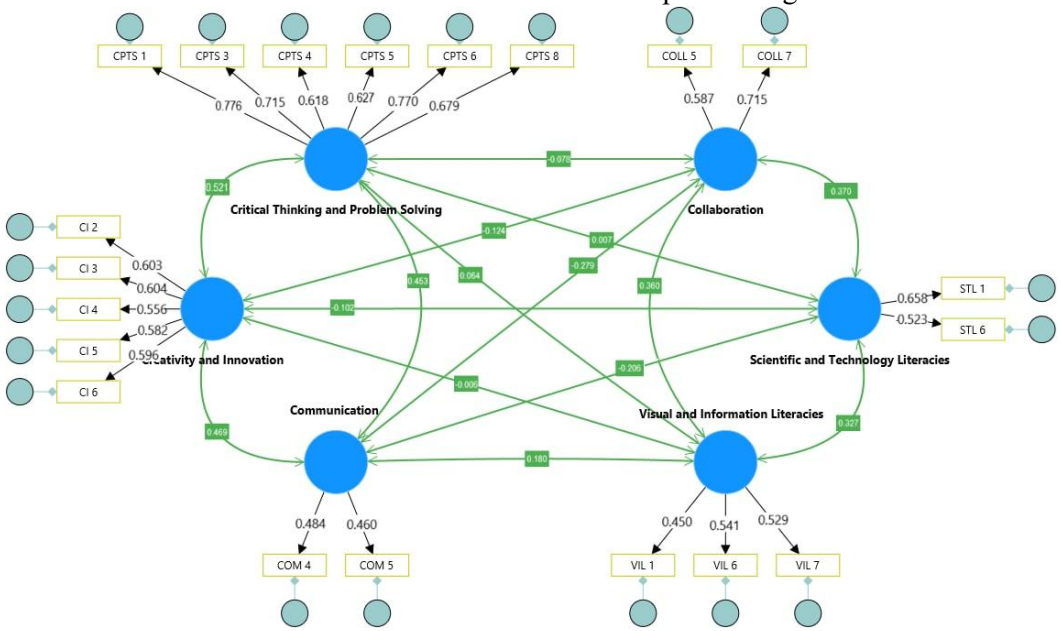

Figure. 2 Correlation Matrix and Factor Loadings using CFA

Figure 2 shows the correlation matrix between skills categories and the refined factor loadings using confirmatory factor analysis. The results are presented in Table 5 and Table 6 and are discussed comprehensively. Based on the correlation matrix, there three groupings of 21st century skills that can be made. The first group includes Critical Thinking and Problem Solving (CTPS), Creativity and Innovation (CI), and Communication (COM). Second group comprises Collaboration (COLL), Scientific and Technology Literacy (STL), and Visual and Information Literacy (VIL). Global Awareness (GA) emerges as an independent factor. Also, the refined factor loadings show the retained items of the revised instrument.

The succeeding tables show the results of correlation matrix and the factor loadings using confirmatory factor analysis.

Table 5. Correlation Matrix Between Skill Categories

	CTPS	CI	COM	COLL	STL	VIL	GA
CTPS	1.000	0.521*	0.453*	-0.078	0.007	0.064	-0.127
CI	0.521*	1.000	0.469*	-0.124	-0.102	-0.006	-0.128
COM	0.453*	0.469*	1.000	-0.279	-0.206	-0.18	-0.164
COLL	-0.078	-0.124	-0.279	1.000	0.370*	0.360*	0.096
STL	0.007	-0.102	-0.206	0.370*	1.000	0.327*	0.068
VIL	0.064	-0.006	-0.18	0.360*	0.327*	1.000	-0.044
GA	-0.127	-0.128	-0.164	0.096	0.068	-0.044	1.000

Note: * indicates significant relationship

Based on the correlation matrix shown in Table 5 and Figure 2 the analyses suggest three distinct groupings of skill categories. The first group includes Critical Thinking and Problem Solving (CTPS), Creativity and Innovation (CI), and Communication (COM). These skills exhibit strong positive correlations with one another, such as $r = 0.521$ between CPTS and CI, and $r = 0.469$ between CI and COM. This indicates that they are closely interrelated and may form a cohesive cluster representing Learning and Innovation Skills (LIS). These skills are fundamental in fostering critical analysis, creativity, and effective communication in problem-solving contexts.

The second group comprises Collaboration (COLL), Scientific and Technology Literacy (STL), and Visual and Information Literacy (VIL). These categories also show significant positive correlations among themselves, such as $r = 0.370$ between COLL and STL, and $r = 0.360$ between COLL and VIL. This grouping highlights the interconnected nature of teamwork and

ISSN:3007-9659 DOI: https://doi.org/10.70114/ahmer.2025.2.1.P115
digital-age literacy skills. This indicates that they are closely interrelated and may form a cohesive cluster representing Collaborative and Digital Literacy Skills.

Lastly, Global Awareness (GA) emerges as an independent factor. Unlike the other skill categories, GA demonstrates weak or negligible correlations with the other domains, suggesting that it functions as a distinct and separate construct within the 21st-century skills framework. This independence highlights the unique nature of global awareness, which may involve a broader, more outward-focused perspective that is less tied to the other skill categories.

These groupings provide insights into the underlying structure of the instrument, supporting its potential use in categorizing 21st-century skills into meaningful domains. This interpretation aligns with the results of the principal component analysis and offers a basis for further refinement of the instrument. The succeeding table provides the final indicators after Refined Factor Loadings using the Confirmatory Factor Analysis.

Table 6. Refined Factor Loadings using the Confirmatory Factor Analysis

Factor	Indicator	Estimate	SE	Z	p
Learning and Innovation Skills	CTPS 1	0.766	0.0945	8.1	< .001
	CTPS 3	0.715	0.096	7.45	< .001
	CTPS 4	0.618	0.0865	7.14	< .001
	CTPS 5	0.627	0.0946	6.63	< .001
	CTPS 6	0.77	0.0921	8.35	< .001
	CTPS 8	0.679	0.0944	7.19	< .001
	CI 2	0.603	0.0908	6.64	< .001
	CI 3	0.604	0.0915	6.6	< .001
	CI 4	0.556	0.0965	5.76	< .001
	CI 5	0.582	0.0851	6.84	< .001
	CI 6	0.596	0.0933	6.39	< .001
	COM 4	0.484	0.0866	5.6	< .001
	COM 5	0.46	0.0962	4.79	< .001
Collaborative and Digital Literacy Skills	COLL 5	0.587	0.112	5.22	< .001
	COLL 7	0.715	0.123	5.83	< .001
	STL 1	0.658	0.139	4.72	< .001
	STL 6	0.523	0.131	4.01	< .001
	VIL 1	0.45	0.13	3.47	< .001
	VIL 6	0.541	0.123	4.39	< .001
	VIL 7	0.529	0.126	4.19	< .001

The refined factor loadings obtained through Confirmatory Factor Analysis (CFA) provide evidence of the robustness of the revised instrument. Table 6 and Figure 2 illustrate that the retained indicators for the two identified clusters, Learning and Innovation Skills and Collaborative and Digital Literacy Skills, have factor loadings equal to or greater than 0.50. This indicates that the retained items have a strong contribution to their respective latent constructs.

Table 7. Global Fit Indices for CFA Model

	χ^2	CFI	TLI	RMSEA	SRMR
Learning and Innovation Skills (13 indicators)	99.2 (65)	0.918	0.902	0.0433	0.0328
Collaborative and Digital Literacy Skills (7 indicators)	14.5 (14)	0.994	0.991	0.0113	0.0581

For Learning and Innovation Skills, 13 indicators were retained, with loadings ranging from 0.484 to 0.77. Notable items such as CPTS 1 (0.766) and CPTS 6 (0.77) demonstrate strong

ISSN:3007-9659 DOI: https://doi.org/10.70114/ahmer.2025.2.1.P115
contributions to the construct, emphasizing the critical importance of creative and critical thinking skills. The global fit indices for this cluster are strong, with a Comparative Fit Index (CFI) of 0.918 and a Tucker-Lewis Index (TLI) of 0.902, indicating good model fit. The Root Mean Square Error of Approximation (RMSEA) of 0.0433 and Standardized Root Mean Square Residual (SRMR) of 0.0328 suggest that the model adequately represents the data and meets acceptable thresholds for model fit.

The Collaborative and Digital Literacy Skills cluster retained 7 indicators, with factor loadings ranging from 0.45 to 0.715. Strong contributors include COLL 7 (0.715) and STL 1 (0.658), underscoring the relevance of collaboration and scientific literacy within this cluster. The fit indices for this factor are excellent, with a CFI of 0.994 and a TLI of 0.991. The RMSEA of 0.0113 and SRMR of 0.0581 further confirm the model's accuracy in representing the data.

Originally, each subscale included 8 indicators. During the refinement process, all items with factor loadings below 0.40 were removed to ensure that only the strongest indicators were retained. As a result, the Global Awareness (GA) factor was completely removed, as none of its indicators met the threshold. This suggests that the GA subscale lacked sufficient alignment with the overarching constructs of the instrument.

The global fit indices for both clusters indicate a robust factor structure for the revised instrument. The high CFI and TLI values suggest strong comparative and incremental fit, while the low RMSEA and SRMR values confirm minimal residual error. These results highlight the validity and reliability of the refined instrument. However, the complete removal of the GA subscale suggests the need for further revisions or a redefinition of this construct to better capture its intended dimensions. Overall, the refinement process has resulted in a stronger and more focused assessment tool for 21st-century skills.

4.3 The Enhanced Self-Assessment Instrument being Developed Based on the Findings of the Study

Table 8 below shows the enhanced self-assessment instrument as final output of this study. The items left are the most reliable and valid based on the results of the study. The development of this self-assessment instrument started with the qualitative phase wherein the researcher was able to capture the perspectives of students and teachers on the 21st century skills. There were 56 items crafted for the 8 sub-variables. The instrument had undergone expert validation, pilot testing, reliability testing and finally the process of refined factor loadings using CFA providing the robustness of the revised instrument. The final instrument contains 20 items and it is named, Self-Assessment Instrument for 21st Century Skills in Science (SAI-21-CSS).

Developing self-assessment instrument for 21st century skills is quite challenging since there are numerous factors to consider from different frameworks. Hence, it is difficult to develop a comprehensive instrument that could cover all domains considering there are several factors from different frameworks of 21st century skills. The following table presents the final items for self-assessment instrument for 21st century skills in science. The results show that these items are valid and reliable.

Table 8. Self-Assessment Instrument for 21st Century Skills in Science

Factors	Generated Indicators
Learning and Innovation Skills	I break down complex problems into simplified components.
	I analyze the problems first and connect them to my prior knowledge.
	I believe accurate answers are derived through personal experiences in laboratory experiments and hands-on activities.
	I gather, express, and support ideas with evidence.
	I evaluate the outcomes by comparing the possible effects of solutions.
	I explore concepts beyond what is presented.
	I contribute original ideas and integrate feedback from peers.

ISSN:3007-9659 DOI: https://doi.org/10.70114/ahmer.2025.2.1.P115

Collaborative and Digital Literacy Skills	I innovate by utilizing domestic or recycled items in doing science projects.
	I love creating science models by using practical materials.
	I like creating visual diagrams to organize my ideas.
	I visualize scientific ideas by presenting them through drawings, mind maps, and diagrams.
	I am confident in sharing experimental results and tasks' outputs with clarity.
	I do not struggle to explain my ideas to my teachers and classmates.
	I cooperate with my classmates by actively participating in group activities.
	I am enthusiastic to work with my classmates to deliver quality outputs.
	I understand science concepts taught in the classroom, and I connect them to real-world situations.
	I use technology in explaining science concepts in the classroom.
	I make sure that the information I search online is timely and relevant.
	I don't rely on any information immediately without verifying the sources.
	I incorporate video animations and visual effects in any science presentations.

5. Summary

This study aimed to develop and validate the researcher-made self-assessment instrument for 21st century skills in science. The items crafted for the self-assessment instrument were based on the results of qualitative data. The refined factor loadings through Confirmatory Factor Analysis (CFA) proves the robustness of the revised instrument. The two identified clusters, Learning and Innovation Skills and Collaborative and Digital Literacy Skills, have factor loadings greater than 0.50. For Learning and Innovation Skills, 13 indicators were retained, with loadings ranging from 0.484 to 0.77. Whilst, the Collaborative and Digital Literacy Skills cluster retained 7 indicators, with factor loadings ranging from 0.45 to 0.715. Originally, each subscale included 8 indicators. During the refinement process, all items with factor loadings below 0.40 were removed to ensure that only the strongest indicators are retained. Finally, the reliability analysis of the instrument demonstrates acceptable internal consistency, with a Cronbach's alpha of 0.76, exceeding the commonly accepted threshold of 0.70. The rigorous methods employed in this study enhanced the instruments' robustness and effectiveness. It also ensures the alignment of its purpose.

Acknowledgment

The authors would like to extend deepest gratitude to all those who have contributed to the success of this study. To the participants who willingly shared their experiences about 21st century skills.

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