

## Profiling Chemical Literacy and 21st Century Skills: Efforts to Develop Effective Chemistry Learning Strategies in Public Schools

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### ABSTRACT

21st-century education demands a transformation towards student-centered learning, yet its implementation in new institutions like Sekolah Rakyat is often hindered by a lack of student profile data. This study aims to map the initial profile of 21st-century skills (4C) and chemical literacy of Grade X students at Sekolah Rakyat 19 Bantul as a diagnostic foundation for developing learning strategies. This study employed a quantitative survey method. The subjects were 40 students selected through total sampling technique. Data were collected using questionnaires for critical thinking, creative thinking, communication, and collaboration skills, as well as a test for chemical literacy skills. Data analysis used descriptive statistics to determine student ability categories. The results showed that communication skills were the most prominent aspect, with 62.5% of students in the high category. Critical thinking skills were dominated by the high category (52.5%), while creative thinking and collaboration skills were mostly in the medium category. Conversely, initial chemical literacy was the lowest aspect, with 67.5% of students in the medium category and 20% in the low category. This study concludes that there is a gap between strong social capital (communication) and low scientific literacy, recommending the implementation of differentiated and contextual chemistry learning strategies to address this disparity.

**KEYWORDS** Profiling, 21st Century Skills, Chemical Literacy, Sekolah Rakyat, Differentiated Learning.



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### INTRODUCTION

Education in the 21st century is tasked with preparing learners to navigate an increasingly complex, interconnected, and rapidly changing world (Assefa, 2024; Rahimi & Oh, 2024). This demands a fundamental pedagogical shift from traditional, teacher-centered instruction towards student-centered approaches that foster critical competencies (Scott, 2023). The essential skills for this era are often encapsulated in frameworks that emphasize life and career skills, learning and innovation skills, and digital literacy. Prominently, the Partnership for 21st Century Skills (P21) has identified the "4Cs"—Critical Thinking, Creativity, Communication, and Collaboration—as crucial learning and innovation skills that students must master to succeed in a globalized society (Zubaidah, 2018). These skills are not merely academic requirements but are fundamental for problem-solving, innovation, and effective participation in the workforce and community life.

Critical thinking skills are the main foundation in problem-solving efforts (Zubaidah, 2018). This skill is very important for students to be able to identify problems and formulate the right solutions. The development of this ability can be done through learning that refers to the P21 indicator, including: (a) the use of inductive and deductive reasoning; (b) analysis of inter-sectional relationships in complex systems; (c) evaluation of facts; (d) drawing conclusions based on analysis; and (e) non-routine problem solving both through conventional and innovative methods.

Furthermore, creative thinking skills are defined as the skill of applying new approaches in discovering and solving problems (Zubaidah, 2018). More broadly, these skills Profiling Chemical Literacy and 21st Century Skills: Efforts to Develop Effective Chemistry Learning Strategies in Public Schools

include the ability to come up with original ideas and explore alternative solutions. The mastery of creative thinking is an important capital for the future success of students (Zubaidah, 2016), one of which can be seen from the achievement of better achievements.

Meanwhile, communication skills are the ability to articulate new thoughts, ideas, and information, both orally and in writing (NEA, 2012). The essence of this competence is the effective delivery of messages to others for a specific purpose. Given that these skills require a process and time, the training must be done on an ongoing basis. Stimulation of communication skills can be done through listening, reading, and observation activities (Zubaidah, 2018). The ability to communicate these ideas plays a very significant role in the learning process (Santos & Semana, 2015).

The last aspect, collaboration, is the ability to work together effectively, fairly, and flexibly in completing team tasks (NEA, 2012). This competency involves active participation in building respectful relationships for the achievement of common goals (Le et al., 2018). The trend of 21st century education has shifted the paradigm from teacher-centered to collaborative learning (Zubaidah, 2018), which is also implemented in the 2013 Curriculum through a student-oriented approach (Ayun, 2021).

The application of personalized learning not only equips students with the competencies to succeed in the global society, but also helps them actualize their potential. This will prepare learners to interact confidently in their communities, both face-to-face and virtual, as well as cross-cultural (Scott, 2023).

In Indonesia, this spirit of transformation has been translated into the latest education policies. This is in line with the demands of education in the modern era which demands a paradigm shift from teacher-centered to student-centered learning. The implementation of the current curriculum, such as the Independent Curriculum, explicitly emphasizes the implementation of differentiated learning. Learning differentiation refers to the diversity of services provided by the characteristics of different learning participants.

In the planning of the teaching process, the characteristics of students need to be known (Callison & Lamb, 2004). Characteristics are defined as a characteristic of each person in their behavior, learning style, and personality. More specifically, Yaumi, M. (2016) explained in his book that character is morality, truth, goodness, strength, and attitude of a person that is shown to others through actions. The good or bad character of the student can be drawn from the morality possessed by the student himself.

The characteristics of learners are very important for educators to know because they are very important to use as a basis for creating teaching strategies (Sutomo & Aini, 2024). Considering that each student has diverse characteristics, understanding and acknowledging these differences is unique and essential in fostering cooperation and a mutually supportive learning process.

This systematic process of identifying these diverse characteristics is known as profiling. According to Ardhyantama & Apriyanti (2021), profiling is an activity to explore special things related to the character or condition of a student that can be observed based on their movements or activities. Profiling can be interpreted as part of the mapping process to find out the special things that students have that are reviewed from their activities. Therefore, profiling is a very important diagnostic first step to personalize the learning experience.

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Although the need for personalized learning based on student profiling is ideal, its implementation in Indonesia faces major challenges, especially seen in learning outcomes in the field of science. Science education in Indonesia has been implemented for many years, but literacy results obtained from PISA are still very low. This low score is caused by the teaching and learning process that focuses on mastering theory, memorization, and evaluation instruments that lack literacy experience (Saraswati et al., 2021). Science literacy is the ability of individuals to identify phenomena, explain, and draw conclusions about issues related to science (Archer, 2014; Saraswati et al., 2021).

This low literacy achievement is confirmed by the latest PISA 2022 Results report published by the OECD. The performance of Indonesian students in mathematics (379), science (398), and reading (371) is still below the average of OECD countries (OECD, 2023). Furthermore, in terms of creative thinking (the third volume of PISA 2022), only around 5% of Indonesian students have managed to reach the top performer category, far below the OECD average of 27% (OECD, 2024). This low achievement is caused by various factors such as a lack of mastery of teacher pedagogy, limited infrastructure, and a learning approach that has not been able to foster high-level thinking skills (Ahmad, 2021). This fact emphasizes the need for transformation and capacity building of teachers to cultivate science literacy skills.

The problem of low literacy is also clearly seen in the context of chemical literacy. Chemical literacy is useful for selecting and correcting facts from scientific information obtained so that conclusions can be drawn and communicated to the public, as well as helping students understand health and environmental issues based on the development of science and technology (Sari et al., 2022). However, the ability to understand chemical literacy in Indonesia is still low. Indicators of identifying and using scientific evidence are the lowest indicators of literacy compared to other indicators (Bagasta et al., 2018; Saija & Namakule, 2019; Zandroto & Sinaga, 2022). This shows that chemistry learning has not involved students to be able to find reasons in explaining scientific phenomena and use existing evidence to draw conclusions and reflections (Zandroto & Sinaga, 2022).

Ideal conditions in education face significant challenges in the context of Sekolah Rakyat, an educational institution that has just been initiated by the government. The People's School is a free education program provided to children from extreme poor families (decile 1), with a boarding school system from elementary to high school. This program aims to break the chains of poverty by providing access to quality and equitable education, not only focusing on academic education, but also character development, life skills, and discipline, with all costs and needs of students covered.

Nonetheless, as a new school, Sekolah Rakyat faces operational challenges in implementing the right learning strategy. The data from this needs questionnaire categorically confirms that the problem faced at Sekolah Rakyat 19 Bantul is the scarcity of systematic student profile data. The findings of the needs questionnaire strongly prove that the research "Profiling Characteristics of Students" is urgently needed, because the results of the study will immediately fill the data gap that is the main obstacle to the implementation of effective chemistry learning at Sekolah Rakyat 19 Bantul.

In addition, based on the results of needs analysis in the form of interviews with teachers at Sekolah Rakyat 19 Bantul, it was found that there was a data gap that was very

critical and urgent to be overcome. Teachers do not have a track record (portfolio) regarding the academic and non-academic development of students. The absence of this data means that the teaching and learning process that is currently taking place has the potential to run without a strong data baseline, so teachers are forced to rely on general assumptions about students' abilities and needs. This lack of initial mapping creates a gap that is urgent to be addressed.

Without accurate student profile data, teachers will have difficulty determining the most relevant teaching methods. The "one-size-fits-all" learning strategy causes some students to feel left behind, unmotivated, or unenthusiastic in learning. Therefore, research to conduct comprehensive profiling (mapping) of student characteristics is very urgent to be carried out. This profiling is not only limited to demographic data, but a diagnostic effort to understand students holistically. This research will focus on two main pillars of profiling: 1) 21st Century Ability: To analyze 21st-century abilities which include critical thinking, creative thinking, communication skills and collaboration skills of learners. 2) Chemical Early Literacy: To measure students' basic conceptual understanding and ability to apply such knowledge in real-life contexts, before further learning interventions are provided.

The status of Sekolah Rakyat as a new school actually provides a golden momentum. Profiling in this early phase will provide enormous benefits. The data generated from this research will serve as a fundamental map for teachers. These maps can be used directly to design more personalized, effective, and inclusive teaching modules, ensuring that each learner gets the right stimulation according to their needs and potential from the beginning of their academic journey at this school.

Based on the explanation that has been presented, the researcher will conduct a research entitled "Profiling Chemical Literacy Ability and 21st Century Ability of Students: Efforts to Develop Effective Chemistry Learning Strategies in People's Schools".

Research Questions 1) What is the profile of the students' initial chemical literacy ability in Sekolah Rakyat? 2) What is the profile of the 21st century abilities (critical thinking, creativity, communication, collaboration) of students at Sekolah Rakyat 19 Bantul?

## **METHOD**

This survey research with a quantitative approach aims to map the profile of chemical literacy and 21st century ability in one of the public schools in Yogyakarta. A sample of 40 (20%) of the class X population was determined by cluster random sampling.

This study uses quantitative research methods. The first stage is the collection of quantitative data through a questionnaire to determine the initial chemical literacy ability of students. The second stage is the collection of quantitative data through students' initial chemistry literacy questions.

The subjects of the study were 40 students of class X of SRMA 19 Bantul and 40 of SRMA Sleman. At the quantitative stage, the sampling technique used is total sampling (saturated sampling).

The data collection in this study is by using tests for chemical literacy and questionnaires for 21st-century ability. The work on the questions and filling out the questionnaire was carried out by the students after the chemistry learning was carried out and the questionnaire was filled out online through a google form that had been shared by the Profiling Chemical Literacy and 21st Century Skills: Efforts to Develop Effective Chemistry Learning Strategies in Public Schools

researcher to all students. The validity of the quantitative instrument is ascertained through expert judgment (content validity) and trial (item validity), while reliability is calculated using Cronbach's Alpha.

The data collection instruments used in this study were questions and questionnaires. Questionnaires and questions are prepared according to the necessary indicators. The creation of the 4C ability questionnaire has been adjusted to P21 (Partnership for 21st Century Learning) is an adoption from Fadhila, et al. with a grid can be seen in Table 1.

**Table 1.** 4C Capability Questionnaire Grid

<b>Yes</b>	<b>Aspects</b>	<b>Indicator</b>
<b>1.</b>	Critical Thinking Skills	Using inductive and deductive reasoning
		Analyze the interconnectedness of each part of the whole
		Analyze and evaluate the facts
		Draw conclusions based on the results of the analysis
		Solve unusual problems (conventional or innovative)
<b>2.</b>	Creative Thinking Skills	Fluency and flexibility of thinking
		Originality and elaboration
		Attitude and creative drive
<b>3.</b>	Communication Skills	Active listening skills
		Speaking clarity
		Non-verbal communication
		Interaction and empathy in a group
		Confidence and assertiveness
<b>4.</b>	Collaboration Capabilities	Contribution and active participation
		Interpersonal and communication skills
		Conflict management and flexibility
		Responsibility and commitment to the goal
		Respect diversity and build a positive atmosphere

Meanwhile, chemical literacy questions are an adoption of the National Exam questions at the junior high school level which are related to chemistry materials.

The questionnaire sheet uses positive and negative statements. For the score on positive statements, namely strongly agree (5), agree (4), neutral (3), disagree (2), strongly disagree (1). For the score on negative statements, namely strongly disagree (5), disagree (4), neutral (3), agree (2), strongly agree (1). After getting data from the results of filling out the questionnaire. The question sheet contains 20 multiple-choice questions with indicators in the form of valid science-chemistry materials adopted from the Junior High School National Exam questions from various age ranges.

Data analysis was carried out using descriptive statistics to map the profile of students' 21st century ability and students' initial chemical literacy skills. The data is sourced from the 4C ability questionnaire (Likert scale).

The description of students' 4C abilities is categorized based on the score of the results of filling out the 4C ability questionnaire by students. In this study, the 4C ability and initial chemical literacy ability were categorized into 3 categories, namely high, medium and low. The calculation of the 4C ability category uses a three-level categorization formula (Azwar, 2007) with the formula can be seen in Table 2.

**Table 2.** 3-Level Categorization Formula

Questionnaire Value	Category
$X < (m - 1s)$	Low
$(m - 1\sigma) \leq X < (m + 1\sigma)$	Keep
$X \geq (m + 1\sigma)$	Tall

Information:

X : Student Values

$\mu$ : Average distribution

S: Standard deviation

Based on table 1, general categorization guidelines for the questionnaire scores of critical thinking skills, creative thinking skills, collaboration skills, and communication skills are presented in Table 2.

**Table 2.** 4C Ability Categorization Guidelines

Questionnaire Value	Category
$X < 35$	Low
$35 \leq X < 55$	Keep
$X \geq 55$	Tall

With this formula, a general category is obtained for chemical literacy skills as presented in Table 3

**Table 3.** Guidelines for Categorizing Early Chemical Literacy Abilities

Question Scores	Category
$X < (m - 1s)$	Low
$(m - 1\sigma) \leq X < (m + 1\sigma)$	Keep
$X \geq (m + 1\sigma)$	Tall

An instrument is said to be valid when it can measure the desired and can reveal data from the variables being studied precisely. Therefore, the instrument used was tested. The instrument testing was carried out by two validators, namely the supervisor and the subject teacher.

## RESULT AND DISCUSSION

### A. Results of Critical Thinking Ability Research

The data from filling out the critical thinking skills questionnaire that has been obtained, then recaps and categorized. Table 3 presented shows the results of the questionnaire on students' critical thinking skills. Table 3 shows 2 students in the low category with 5%, medium category as many as 17 students with 42.5% and high category as many as 21 students with a percentage of 52.5%.

**Table 3.** Distribution of Critical Thinking Skills Category

Category	Frequency
Low	2
Keep	17

Tall	21
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In critical thinking skills, there are 4 indicators assessed by researchers. The following are the results of the assessment of each indicator of critical thinking ability for all research subjects presented in Table 4.

**Table 4.** Distribution of Assessment Results by Critical Thinking Ability Indicator

Yes	Category	Percentage
1.	Using inductive and deductive reasoning	69%
2.	Analyze the interconnectedness of each part of the whole	75%
3.	Analyze and evaluate the facts	77%
4.	Draw conclusions based on the results of the analysis	77%
5.	Solve unusual problems (conventional or innovative)	77%

### B. Research Results of Creative Thinking Ability

The data from filling out the creative thinking ability questionnaire that has been obtained, then recaps and categorized. Table 5 presented shows the results of the questionnaire on students' creative thinking skills. Table 5 shows 2 students in the low category with 5%, medium category as many as 25 students with 62.5% and high category as many as 13 students with a percentage of 32.5%.

**Table 5.** Distribution of Creative Thinking Ability Categories

Category	Frequency
Low	2
Keep	25
Tall	13

In creative thinking ability, there are 3 indicators assessed by researchers. The following are the results of the assessment of each indicator of critical thinking ability for all research subjects presented in Table 6.

**Table 6.** Distribution of Assessment Results by Creative Thinking Ability Indicator

Yes	Category	Percentage
1.	Fluency and flexibility of thinking	67%
2.	Originality and elaboration	69%
3.	Attitude and creative drive	67%

### C. Communication Ability Research Results

The data from filling out the communication skills questionnaire that has been obtained is then recapped and categorized. Table 7 presented shows the results of the students' communication ability questionnaire. Table 7 shows 15 students in the medium category with 37.5% and 25 students in the high category with a percentage of 62.5%.

**Table 7.** Distribution of Communication Ability Categories

Category	Frequency
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Low	0
Keep	15
Tall	25

In communication skills, there are 5 indicators assessed by researchers. The following are the results of the assessment of each indicator of critical thinking ability for all research subjects presented in Table 8.

**Table 8.** Distribution of Assessment Results by Communication Ability Indicator

Yes	Category	Percentage
1.	Active listening skills	74%
2.	Speaking clarity	75%
3.	Non-verbal communication	77%
4.	Interaction and empathy in a group	75%
5.	Confidence and assertiveness	75%

#### D. Research Results of Collaboration Ability

The data from filling out the collaboration ability questionnaire that has been obtained is then recapped and categorized. Table 9 presented shows the results of the questionnaire on students' collaboration skills. Table 9 shows 26 students in the medium category with 65% and 14 students in the high category with a percentage of 35%.

**Table 9.** Collaboration Capability Category Distribution

Category	Frequency
Low	0
Keep	26
Tall	14

In collaboration ability, there are 5 indicators assessed by researchers. The following are the results of the assessment of each indicator of critical thinking ability for all research subjects presented in Table 10.

**Table 10.** Distribution of Assessment Results by Collaboration Capability Indicator

Yes	Category	Percentage
1.	Contribution and active participation	75%
2.	Interpersonal and communication skills	76%
3.	Conflict management and flexibility	70%
4.	Responsibility and commitment to the goal	75%
5.	Respect diversity and build a positive atmosphere	64%

#### E. Research Results of Chemical Literacy Initial Ability

The data from filling in the initial chemical literacy skills that have been obtained, are then recapped and categorized. Table 11 presented shows the results of students' initial chemical literacy skills. Table 11 shows that 8 students in the low category with 20%, in the medium category as many as 27 students with 67.5% and in the high category as many as 5 students with a percentage of 12.5%.

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**Table 11.** Distribution of Initial Chemical Literacy Ability Scores

Question Scores	Category	Frequency
$X < 33.33$	Low	8
$33.33 \leq X < 66.67$	Keep	27
$X \geq 66.67$	Tall	5

## Discussion

This study aims to map the initial profile of 21st century (4C) abilities and chemical literacy of class X students at Sekolah Rakyat 19 Bantul. This profiling is a crucial diagnostic step to design effective and differentiated learning strategies, given the diverse backgrounds of students and the school's status as a boarding institution.

The results showed that students' critical thinking skills were relatively good, dominated by the High (52.5%) and Medium (42.5%) categories. The results of this finding are quite positive considering that critical thinking is a fundamental reasoning thought in problem solving in the 21st century.

Specifically, the indicator "Analyzing and evaluating the facts" obtained the highest percentage of 77%. This indicates that students in the People's School have good metacognitive awareness to evaluate their own thinking. However, the indicator "Using inductive and deductive reasoning" was the lowest (71%). In fact, reasoning skills are very necessary in dealing with problems in the 21st Century. In line with Lawson in Sukmadinata (2004) states that according to Piaget's theory, the development of formal reasoning skills is very important for the acquisition (mastery) of concepts, because conceptual knowledge is the result or result of a constructive process, and the reasoning ability is a necessary tool in that process.

Although learners are able to reflect on themselves, they still face challenges in dissecting complex information analytically. This is in line with Erikson's (2019) theory that critical thinking is related to cognitive skills because it involves problem-solving activities; understand the interaction of factors influencing outcomes; and calculate various possibilities and scenarios to make informed decisions.

Critical thinking skills must be possessed by students in order to be able to face personal and social problems in their lives in the future. Critical thinking skills require constant practice to analyze the interconnectedness of parts in complex systems. In the context of chemistry learning, learning strategies must emphasize more on case studies or problem-based learning to hone the ability to analyze facts.

In contrast to critical thinking, the majority of students' creative thinking skills are in the Medium category (62.5%), with only 32.5% in the High category.

The indicators "Fluency and flexibility of thinking" and "Attitude and creative drive" obtained the lowest percentages at 67%. Low flexibility of thinking shows that students tend to be fixated on one way of solving problems and lack the courage to explore new approaches. In fact, creative thinking requires the ability to generate new ideas and find many possible solutions.

This data is relevant to the OECD report (2022) which states that the creative thinking skills of Indonesian students still need to be improved. Teachers need to facilitate a learning

environment that triggers "Creative attitudes and encouragement" so that students are not afraid of making mistakes in coming up with original ideas.

Communication skills are the most prominent aspect, where 62.5% of students are in the High category and no students are in the Low category. The indicator "Non-verbal communication" achieved the highest score (77%).

This high communication ability is most likely supported by the boarding school system (dormitory) in Sekolah Rakyat. Intensive interaction between learners in daily life trains them to express opinions and understand non-verbal cues naturally. This ability is an excellent social capital, as effective communication is a prerequisite for collaboration and the delivery of scientific ideas. However, the lowest indicator of "Active listening skills" (74%) indicates the need for a habit of more structured discussions in the classroom so that students can be more patient in listening to their friends' arguments.

The majority of students' collaboration skills are in the Medium category (65%). Although they are able to work in groups, there is an important note on the indicator "Respecting diversity and building a positive atmosphere" which is the lowest indicator (64%).

This finding is interesting to observe in the context of boarding schools. Despite high interaction (good communication), conflicts between students may hinder the creation of a consistent positive atmosphere in group work. In fact, collaboration requires flexible, fair, and respectful work. Collaborative chemistry learning should be designed not only to complete tasks, but also to instill the value of mutual respect for differences of opinion as part of 21st century soft skills.

Among all variables, chemical literacy showed the lowest results. Most of the students were in the Medium category (67.5%) and there were 20% of students in the Low category. Only 12.5% reached the High category.

This low initial chemical literacy confirms the national trend where the science achievement of Indonesian students in PISA is still low. This low score indicates that learners are not used to using scientific evidence to draw conclusions or explain phenomena, as defined in science literacy.

This is likely due to previous learning experiences that were more teacher-centered than contextual understanding. The lack of association of chemical materials with socio-scientific issues (such as the environment and health) makes it difficult for students to answer literacy questions that require a high level of reasoning.

## CONCLUSION

Overall, the results of profiling at Sekolah Rakyat 19 Bantul revealed that there is a significant competency gap between social capital and students' academic readiness. Students have the main strength in communication and critical thinking skills which are dominated by the high category, a positive achievement stimulated by intensive interaction in the boarding school environment. However, this social potential has not been balanced by cognitive flexibility and mastery of science content, where creative thinking and collaboration skills are still held in the medium category due to a lack of courage to explore new ideas and challenges in respecting diversity. The most critical condition was seen in chemical literacy which was the weakest aspect with 20% of students in the low category, which indicated the Profiling Chemical Literacy and 21st Century Skills: Efforts to Develop Effective Chemistry Learning Strategies in Public Schools

negative impact of previous learning history that was teacher-centered. Therefore, this data emphasizes the urgency of implementing differentiated and contextual chemistry learning strategies to bridge the disparity between good social skills and low science literacy. Overall, this profiling reveals a gap. People's School students have strong social capital potential (high communication, good critical thinking), but are still weak in terms of academic content (chemical literacy) and flexibility of ideas (creative thinking). This data emphasizes the urgency of implementing a learning strategy that: Differentiated: Accommodating 20% of students with low chemical literacy so as not to be left behind, while challenging students in the medium/high category. Contextual & Inquiry: Improve chemical literacy by reducing memorization and increasing the investigation of real phenomena to train analysis (improve low critical analysis indicators). Student-Centered: Shifting the teaching paradigm to provide space for students to develop creativity and self-determined learning. The results of this profiling are a valid baseline for teachers of Sekolah Rakyat 19 Bantul to design teaching modules that are right on target, so that the learning process is no longer based on mere assumptions.

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