Critical Thinking Skills in Research Process, a Literature Review. An Input to Propose a New Measurement Instrument to Gauge Critical Thinking

Eunice Ayala[1], Walter Fuertes[2] and Freddy Jarrin[3]

Abstract

Critical thinking is crucial in research skills because it enables individuals to make better decisions, solve problems, and understand complex issues. For this reason, enhancing it at all educational levels is essential. This study aimed to perform a meta-analysis of the most common critical thinking skills (CTS). This was carried out through a systematic literature review based on the methodology of Barbara Kitchenham. The review revealed 29 articles that met the inclusion and exclusion criteria. The outcomes showed that the most featured critical thinking skills are analysis, interpretation, evaluation, inference, and self-regulation. Findings, also demonstrate that 83% of the different teaching methodologies applied at different educational institutions, clearly, contribute to develop students´ CTS. Critical thinking skills training for teachers and students, gender analysis, application of new strategies to enhance critical thinking, and their subsequent evaluation are some of the current challenges and future areas of research, which are essential for further advancement of this topic. Based on these inputs, we propose innovative ideas to tailor a new measurement instrument to assess CTS that will give guidelines on stimulating critical thinking as a skill in the research process for Ecuador's higher education students; it mainly contains three phases, initiation, inference and assumption.

Keywords: *Education, Critical Thinking, Critical Thinking Skills, Scientific Research Methods, And Tests to Measure Critical Thinking.*

INTRODUCTION

Critical thinking is one of the most important scientific research skills. It has become an essential goal for the education systems of different countries since it plays a crucial role in scientific research to generate new knowledge (Vázquez-Villegas et al., 2023). It leads students to afford problems and changes related to economic, social, environmental, and health problems, the rapid development of science and technology, wars, and terrorist attacks. Indeed, critical thinking is widely recognized as one of the essential 21st-century skills, mainly because it influences scientific research.

The importance of critical thinking drives academic achievements and directly impacts professional success and employability. Employers highly value critical thinkers because they can effectively solve problems, adapt to changes, and contribute new knowledge and innovative ideas to the workplace. Since companies and industries have become more dynamic and uncertain, the ability to think critically becomes a distinctive qualification for job candidates.

Due to the previous context, several researchers provide a comprehensive understanding of critical thinking competencies and their importance in scientific research. They firmly emphasize the importance of strengthening these skills to develop effective decision-making, problem-solving, and cognitive development. Ghaani M. & Pauline Roslin V. (Ghaani & Roslin, 2021), (Al-Rahbi et al., 2022), (Esparrago, 2021), (Poštić et al., 2023), (Basri et al., 2019), (Sari & Aminatun, 2021), (Xu, 2018).

Several countries are revising their critical thinking and research skill development methodologies as they impact research, student studies, and careers. For example, methods like reciprocal teaching (Noroozi, 2023), (Mafarja et al., 2022) and flipped classrooms (Yulian, 2021) are under analysis.

Improving critical thinking competencies to enhance research processes that students conduct in countries worldwide is a multidimensional activity that demands considering different challenges and exploring future research lines. These include teacher training and professional development (Songsil et al., 2019), (Wang,

---

[1] Universidad de las Fuerzas Armadas-ESPE. E-mail: ecayala@espe.edu.ec

[2] Universidad de las Fuerzas Armadas-ESPE.
[3] Universidad de las Fuerzas Armadas-ESPE.

2021), new assessment methods, the impact of gender on CTS development, (Lee et al., 2019), new teaching strategies to develop CTS (Poštić et al., 2023b), (Sari & Aminatun, 2021), (Xu, 2018), (Mafarja et al., 2022), (Yulian, 2021), (Mahdi et al., 2020), (Hirai et al., 2022), (Yaki, 2022).

Scientific research is utilizing and expanding scientific knowledge, which involves assessing and analyzing current data and gathering new data. It refers to a set of theoretical, methodological, and technical procedures researchers use to advance knowledge. Students assert that scientific research is designed to collect, interpret, and assess information to contribute to scientific progress. These definitions reveal that the primary goal of scientific research is to generate knowledge. In modern science, research papers are the standard output of scientific investigations, although various types of research can produce different forms of production, such as products and patents. (Vázquez-Villegas et al., 2023), (Chen et al., 2023).

To develop research skills like formulating hypotheses, identifying evidence, combining different evidence, and arguing reasoning, fieldwork and direct interaction with the environment are also applied. This helps to bridge the gap between theoretical knowledge and the development of field-specific skills. It's important to note that completing academic courses before fieldwork is essential. (Vázquez-Villegas et al., 2023)

The main aim of this study is to conduct a meta-analysis of the most prevalent critical thinking skills, analyzing the different approaches used in their development and the other tests employed for their measurement. The contributions of this study are as follows:

To determine which critical thinking skills have been most studied through the different research regarded in this SLR;

To establish the different methodologies applied to develop CTS and research skills in students to improve research processes;

To provide information about several CTS that have been applied, and to measure them;

The most important contribution is to state a proposal that can be used to tailor tests to evaluate CTS of Ecuador's higher education students, ensuring its relevance and applicability in the local context.

We conducted a systematic literature review, following the methodology of Barbara Kitchenham, to analyze different studies available across various search engines and databases. After filtering through the studies, we found 29 articles that met the selection criteria. Our analysis revealed several methodologies to enhance students' critical thinking skills, a vital soft skill required across various industries. However, further research and development are needed to implement specific strategies effectively. Additionally, evaluating critical thinking skills through assessment tools presents a challenge that needs to be addressed, considering the current demands of our society.

The rest of the article is structured as follows. The second part, explains the methodological process used. The third section, presents the results obtained and the fourth part describes the proposal to design a new measurement instrument that serves as an input to stimulate critical thinking in students of a higher education institution to increase research skills. The article ends with the conclusions and lines of future work.

MATERIALS & METHODOLOGY

We consider the guidelines of Barbara Kitchenham (Kitchenham et al., 2009) for the Systematic Literature Review (SLR). Then, we formulated research questions and explored them based on search strings. Afterward, we applied inclusion and exclusion criteria to evaluate the quality of selected articles. Finally, we performed data extraction, analysis, and synthesis to visualize them.

Research Questions and Objectives

To delimitate and fulfill the purpose of this study, we established four research objectives derived from the research questions: (i) To determine the most common critical thinking competencies; (ii) To analyze the methodologies applied to develop students' critical thinking competencies and scientific research skills; (iii) To assess the tests that have been

developed to measure critical thinking competencies; (iv) To determine the future challenges and research lines.

Search the Relevant Documents

We used the following search engines and databases to find the primary studies: Scholar Google, Semantic Scholar, Research Gate, Springer Open, and Scopus.

Define Search Terms (Search String)

This study aims to obtain relevant information from primary sources on critical thinking skills applied in scientific research, developing methodologies, tests to measure, future challenges, opportunities, and research lines. For this purpose, the following search strings were entered into search engines and databases:

"Critical thinking" AND "assumption skill" AND "higher education" > 2018;

"Deduction as a critical thinking subskill" AND "higher education" > 2018;

"Critical thinking skills" AND "Ecuador" AND "higher education" AND "quantitative studies" AND "methods to develop scientific research skills" AND "deduction" AND "assumption".

("Critical thinking") AND ("higher education" OR universit* OR "scientific research")

("Critical thinking") AND ("higher education" OR universit* OR "scientific research") AND NOT ("artificial intelligence" OR gpt*)

((("critical thinking") AND ((skill* OR subskill*) AND ("higher education" OR universit* OR "scientific research"))) AND NOT ("artificial intelligence" OR gpt*)))

Inclusion And Exclusion Criteria

After searching and selecting information sources, we reviewed 2018 and 2024 to assess the studies' topicality, originality, contribution, and quality. In addition, the articles were primarily studies written in English obtained only from journals, especially those that included quantitative results. On the other hand, we excluded books, theses, and papers from scientific congresses and conferences.

RESULTS AND DISCUSSION

The SLR assesses and explains relevant research in relevant topics or areas of interest. Thus, to ensure research quality, only primary studies were considered. These studies analyzed common critical thinking competencies in students and future employees. They also introduced recent methodologies for enhancing students' critical thinking skills for scientific research. The authors of the reviewed studies included suggested tests, inventories, and scales to measure the students' critical thinking skills. Likewise, we welcome those who propose future lines of research based on essential critical thinking skills in the 21st century. We did not consider qualitative and systematic literature reviews. After reading the abstracts and conclusions, we read 29 complete primary studies that met the inclusion and exclusion criteria.

This section presents the results of the SLR. Here, we analyzed, interpreted, and displayed according to each established research question for a better understanding.

RQ1: What Are The Most Common Critical Thinking Skills Analyzed?

Several studies have most commonly inquired about the following critical thinking skills and subskills:

Argumentation: Defending the allegation of one's position, listening to, analyzing, and evaluating other people's claims to respond to them and make conclusions. Argumentation is a vital subskill of critical thinking that plays a significant role in scientific research. Argumentation involves constructing and evaluating arguments, which are logical and evidence-based justifications for a particular claim or position (Noroozi, 2023), (Yulian, 2021).

Interpretation: Be able to categorize, decode significance, clarify the meaning of situations, phenomena, experiences, rules, and procedures, and communicate that information to others. It plays a crucial role in scientific research. It involves analyzing and making sense of data, observations, and evidence, leading to

meaningful and informed conclusions. (Ghaani & Pauline Roslin, 2021), (Al-Rahbi et al., 2022), (Poštić et al., 2023).

Analysis: Ability to examine ideas, identify reasons, arguments, and claims, as well as relationships among descriptions, concepts, statements, or opinions. It allows researchers to break down complex problems into manageable components, identify patterns in data, and draw meaningful insights. It helps researchers make data-driven decisions and draw conclusions based on empirical evidence. (Ghaani & Pauline Roslin, 2021), (Al-Rahbi et al., 2022), (Songsil et al., 2019), (Poštić et al., 2023), (Yulian, 2021), (Lee et al., 2019), (Wong et al., 2022).

Evaluation: Involves query evidence and analyzes alternatives. Critical thinkers usually assess the credibility and validity of evidence. In scientific research, this involves scrutinizing data, experimental methods, and sources of information. Researchers with solid evidence evaluation skills are more likely to detect flawed studies or misleading data, which can lead to more reliable conclusions. (Ghaani & Pauline Roslin, 2021), (Al-Rahbi et al., 2022), (Songsil et al., 2019), (Poštić et al., 2023), (Yulian, 2021), (Lee et al., 2019), (Wong et al., 2022).

Inference: make logical conclusions on observed situations, phenomena, or what we already know "to form conjectures and hypotheses; to consider relevant information and to deduce the consequences flowing from data, statements, principles, evidence, judgments, beliefs, opinions, concepts, descriptions, questions, or other forms of representation." This skill includes three subskills: "querying evidence, conjecturing alternatives and concluding" (Ghaani & Pauline Roslin, 2021), (Al-Rahbi et al., 2022), (Poštić et al., 2023), (Yaki, 2022).

Explanation: Clarify or provide understanding about a concept, phenomenon, or situation. It involves stating results, edifying procedures, and presenting arguments. It is defined as "contextual considerations upon which one's results were based and to present one's reasoning in the form of cogent arguments." The experts classified "stating results," "justifying procedures," and "presenting arguments" as the three subskills of the explanation skill. (Ghaani & Pauline Roslin, 2021), (Al-Rahbi et al., 2022b), (Poštić et al., 2023b).

Self-regulation: to control and manage one's thoughts, emotions, and behavior "self-consciously to monitor one's cognitive." It encompasses these subskills: self-examination, self-correction, self-control, and self-motivation. (Ghaani & Pauline Roslin, 2021), (Al-Rahbi et al., 2022b), (Poštić et al., 2023), (Wong et al., 2022).

The subskills proposed by Sari & Amination in 2021, namely "elementary clarification" and "bases for a decision," play a crucial role in the processes of explanation and analysis. (Sari & Aminatun, 2021) Let's delve deeper into these subskills to understand their significance:

Elementary Clarification: It involves breaking down complex concepts, ideas, or problems into more straightforward, understandable components. It is the process of untangling and presenting intricate information clearly and coherently. When engaging in explanation, this subskill helps the researchers to organize their thoughts and articulate the subject matter effectively to the audience.

Bases for a Decision: It refers to the fundamental factors or criteria used to make informed choices or judgments. In the context of explanation, when presenting a decision-making process or the reasons behind a particular option, it is essential to outline the basis upon which the decision was made. This subskill adds transparency and credibility to the explanation, allowing the audience to understand the rationale behind the decision and evaluate its soundness (Chen et al., 2023). Decision-making plays a significant role in scientific research. It involves selecting the best course of action or making informed choices based on available evidence, logical reasoning, and evaluating potential outcomes.

In analysis, establishing clear bases for a decision is critical for making well-informed and objective judgments. Analysts must identify and evaluate various factors, data points, and relevant information contributing to the decision-making process. By clearly defining the basis for a decision, the analysis becomes more robust and can withstand scrutiny, as it is grounded in logical and justified reasoning.
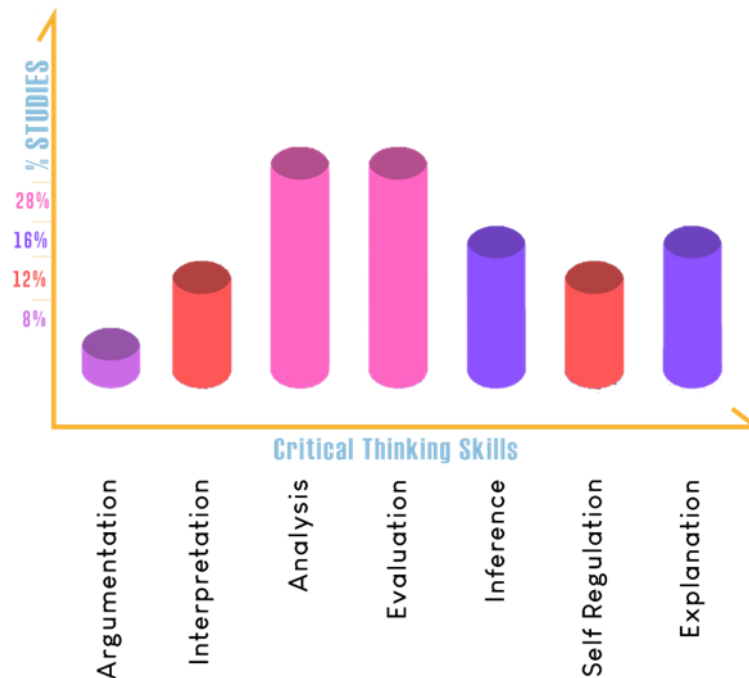
Figure 1. "Analysis of Critical Thinking Skills in Systematic Review Studies."

Several pieces of research predominantly studied analysis and evaluation, as shown in Figure 1.

Overall, the subskills of elementary clarification and bases for a decision are closely intertwined with the processes of explanation and analysis. They provide a solid framework for effective communication and critical thinking, ensuring that information is coherent and understandable while facilitating informed decision-making. These subskills are valuable in academic and professional settings and everyday life when conveying ideas or making well-considered choices. (Xu, 2018), (Lee et al., 2019).

Furthermore, there are other critical thinking skills such as credibility, deduction, induction, assumption identification (Esparrago, 2021), supposition and integration (Sari & Aminatun, 2021), defining, summarizing, parsing, identifying facts and opinions, discerning fallacies, applying principles, predicting, and solving problems (Xu, 2018) which are mentioned. Nonetheless, they have yet to be deeply analyzed.

Likewise, there is another statement on critical thinking skills presented at the World Economic Forum in 2016 that proposes three subskills: The ability to identify and analyze problems in complex or ambiguous situations and develop justification evaluation (CTPS-1), the ability to improve and develop thinking skills such as to explain, analyze, discuss and evaluate (CTPS-2); the ability to generate the ideas and alternative evaluation (CTPS-3). (Mafarja et al., 2022).

RQ2: What methodologies have been applied to develop critical thinking skills and research skills in students to improve research processes?

Since critical thinking is one of the skills that students must develop in the 21st century, authors applied several methodological approaches to reach that goal at different educational institutions, as described in the following paragraphs:

Approach 1: Reciprocal Teaching

Definition: It is a method that promotes active learning and comprehension of a text through structured group discussions. It involves a collaborative dialogue between the teacher and students. Four main strategies are applied: predicting, questioning, clarifying, and summarizing. Students develop metacognitive skills by actively monitoring their comprehension, identifying difficulties, and employing strategies to overcome them. It

encourages critical thinking, collaboration, and a deeper understanding of the text. By engaging in meaningful discussions and sharing their interpretations, students develop their ability to construct meaning, evaluate information, and actively enhance their overall comprehension skills. (Mafarja et al., 2022)

Reciprocal teaching lays a strong foundation for students to become proficient researchers who can approach their work with critical thinking, curiosity, and confidence by fostering critical reading, questioning, collaboration, and metacognitive awareness

• Outcomes: A quasi-experimental study involving four groups and 120 participants assessed critical thinking skills in physics before and after implementing reciprocal teaching. Through Multivariate analysis of covariance (MANCOVA) and a two-way MANCOVA process, it was observed that reciprocal teaching significantly improved critical thinking skills. Notably, this teaching method had a substantial positive impact on enhancing students' cognitive and metacognitive abilities at the secondary level.

Approach 2: Flipped Classroom

Definition: The flipped classroom is an instructional approach where traditional teaching methods are reversed or "flipped." This model exposes students to instructional content, such as lectures, readings, online videos, or resources. Before attending the in-person class session, they can access these materials at their own pace and convenience. This education model fosters profound understanding, critical thinking, and active participation. Further, researchers can focus on developing practical research skills, such as data analysis, experimental design, and critical discussions about research methodologies, improving their overall research competence. (Yulian, 2021)

Outcomes: Based on the findings of a quasi-experimental study, implementing the Flipped classroom teaching model resulted in notable enhancements in students' critical thinking abilities, particularly concerning their reading skills. The improvements were observed in various aspects, including accuracy, clarity, precision, depth, relevance, and logic. The exposure to instructional videos and materials played a crucial role in enabling students to apply logical concepts and content to broader reading contexts.

Approach 3: Case Study

Definition: Mahdi et al., states that the case study educational approach involves using natural or fictional cases as a central focus for teaching and learning. It is a method that enables students to explore and analyze complex situations, problems, or scenarios in a practical and applied manner. A case study involves an in-depth and comprehensive exploration of a single individual, group, event, or phenomenon. (Mahdi et al., 2020)

Outcomes: Concerning the case study method, students' critical thinking abilities can be greatly improved, allowing them to analyze and resolve problems while engaging in group discussions effectively. As a result, a significant increase is observed in students who actively scrutinize, interpret, evaluate, deduce and employ inductive and deductive reasoning.

Approach 4: Revised Argument-Driven Inquiry (rADI)

Definition: Sampson et al., in Songsil et al., 2019, assert that the Argument-Driven Inquiry model is an educational framework that focuses on developing students' critical thinking, scientific reasoning, and argumentation skills through inquiry-based learning.

Outcomes: When using the traditional teaching method, students enhanced their overall argumentation score by about 2% and their use of supportive arguments by about 1%. In contrast, when students used the rADI method, students improved their overall score by about 10% and their supportive argument skill by about 11%.

Approach 5: Cooperative Based Learning Model (CAP-Based Learning Model)

Definition: Method to enhance learning motivation, academic achievement conceptual understanding since more knowledgeable students support the low ones. On the other hand, when students work cooperatively, they can improve information retention, engagement motivation, critical thinking and problem-solving skills.

Further, the combination of cooperative learning method, mobile apps and augmented reality promotes students´ critical thinking skills and motivation.

Outcomes: After working with an experimental and control group, the results indicate that the experimental group after receiving the CAP-based learning treatment showed high level of critical thinking while the control group showed a moderate improvement. Moreover, the CAP-based learning model enhanced the students´ motivation of the experimental class.(Rizki et al., 2024)

Approach 6: Multiple Intelligence-Based Differential Learning

Definition: First, teachers identify the type of intelligence students possess, then, introduce differential instruction to suit different kinds of intelligences that each student has. Thus, students will be able to develop and maximize their potential and learning achievement. Teachers design a variety of strategies in order students get involved in their own learning process and create learning products through information related to real-world issues. (Alhamuddin et al., 2023)

Outcomes: The data showed that the common level of critical thinking skill before being trained through the differential instruction was 56.19. After, students received the differential education the capacity to think critically got an average of 84.55, hence, the multiple intelligence-based differential method could improve students´ ability to think critically. (Alhamuddin et al., 2023)

RQ3: Which tests have been developed to measure critical thinking subskills Critical Thinking skills?

The measurement of CTS involves assessing a person's ability to analyze, evaluate, and synthesize information to make reasoned judgments and decisions. Table 1 includes seven instruments for evaluating critical thinking.

Table 1 *Instruments to measure CTS*

TEST	DESCRIPTION	RESULTS
Critical Thinking Skill Test (CTST). (Mahdi et al., 2020c)	The CTST was developed based on the Watson-Glaser Critical Thinking Test model, which refers to the five sub-skills: argument, assumption, Deduction, Interpretation, and Conclusions (A2DIK).	Although capable of bridging the character of curiosity, CTST test has not been able to describe the critical thinking skills of students in the form of problem-solving.
English test measuring EFL learner's critical thinking skills. (Hirai et al., 2022b)	The English Critical Thinking Test (ECTT) was designed to measure critical thinking skills' consistency, analysis, and inference. It is a follow-up to a pilot study to accumulate valid evidence for using the ECTT.	"The ECTT was adequate for university students of English since it is useful for teachers to identify their CT skills to learn English and analyze the adequate method to enhance them. But there are some issues to regard, since it is necessary to create items to measure higher-order CT skills. "
Critical thinking scale to measure the 3D critical thinking ability of EFL readers (Mohammadi et al., 2022)	"It is based on the Assessing criteria of CTI proposed by Mohammedi et al. (Characterization and Development of Critically-thinker EFL Readers' Reading Ability: Asynchronous Web-based Collaborative vs. Question-Answer - Relationship Instructional Approach) in determining the critical thinking ability in three different layers (i.e., individual critical thinking skills, criticality, and critical pedagogy)"	"Model with six scales and twenty-two subscales indicate a good fit representing that argumentation, judgment, disposition, action, social cognition, and creativity are proper components for measuring three-level critical thinking in language learners. Further, the combination of the results of covariance analysis, the three-level analyses, and the reliability calculations, shows that the questionnaire is valid and reliable."
Critical Thinking Skills Inventory: RASCH and Confirmatory Factor Analysis Approaches. (Song et al., 2020a)	"It measures students on their attainment of critical thinking skills after taking a module on critical thinking and problem solving. It consists of five elements of critical thinking: Interpretation, Analysis, Evaluation, Inference and Explanation."	"The items in this final scale have shown acceptable internal consistency. Item-total correlation values of the manifest variables were of reasonable standards. Further, the Rasch analysis conducted in the pilot testing phase indicated that the items in the scale were widely diversified to meet the differing abilities of the students in critical thinking skills."

Rubric for Assessing Critical Thinking Skills in Problem Statement (RACTSPS) to rate the problem statement section. University Technology of Malaysia. (Sharif et al., 2022)	Evaluates the problem statement of theses sections, regarding students guided by the correct strategies when writing them. This rubric was tailored based on thematic analysis from previously developed models.	This rubric is useful for instructors to determine which skills should be taught in Writing problem statement in thesis.
PENCRISAL test - Portuguese short version: a psychometric study. University of Salamanca, Spain.(Rivas et al., 2023)	A critical thinking assessment test for higher education students, it contained CT skills related to inductive Reasoning/induction, deductive reasoning/deduction, and practical reasoning (three of the five dimensions of the original short version of the PENCRISAL test, explained above).	This critical thinking assessment test for higher education students was designed and validated in Spain (full and short version). It presents adequate reliability and validity psychometric characteristics to assess key dimensions of critical thinking.
CLA + International Test (Collegiate Learning Assessment). (Kleemola et al., 2022)	"It measures critical thinking and written communication skills in higher education in a domain-general manner: analysis and problem-solving (APS), writing effectiveness (WE) and writing mechanics (WM), quantitative reasoning (SQR), critical reading and evaluation (CRE) and critiquing an argument (CA)."	"Although CLA + Internacional measures key critical thinking skills, it has been questioned whether it is able to capture critical thinking (Aloisi and Callaghan 2018). More extensive investigations are needed on validity considering cognitive processes. (American Educational Research Association, American Psychological Association, and National Council on Measurement in Education 2014)."

Although critical thinking is one of the most important skills in scientific research, only 21% of the articles considered in this study, mainly propose new CTS tests, scales and inventories, as figure 2 shows.
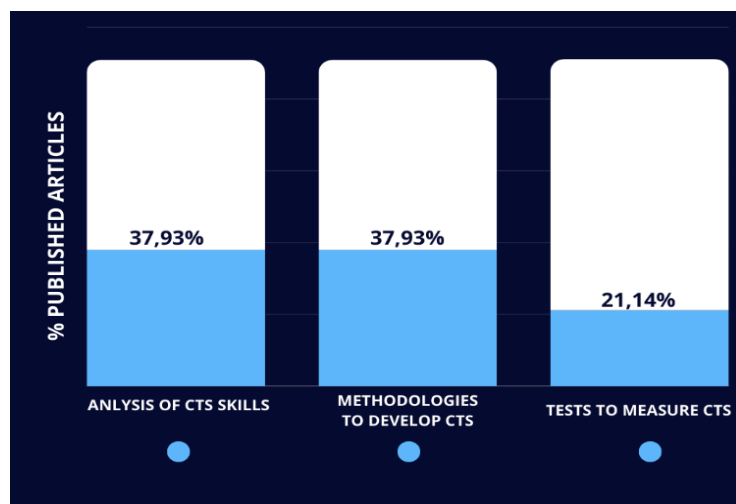

Figure 2. Articles on CTS skills, methodologies and CTS tests

RQ4: What future opportunities, challenges, and research in this topic exist?

According to the research results, which have been considered to conduct this study, several challenges must be met, and future research lines must be considered in future investigations and proposals, as shown in Table 2 and Figure 3 and 4.

Table 2. *Challenges*

Item	Description
1	Integrate critical thinking across all courses offered in teacher education programs or establish dedicated procedures that provide teachers with practice opportunities in critical thinking (Ghaani & Pauline Roslin, 2021)
2	Analyze the integration of critical thinking skills in teaching English activities and resources, for instance, textbooks (Al-Rahbi et al., 2022b).
3	Explore the constraints of implementing methodologies such as the reciprocal teaching strategy, flipped classroom, STEM education, case studies, problem-solving, and instructional pedagogy that incorporates directed learning activities. In addition, Bloom's Taxonomy should

|	
	also be included in different subject areas, such as Mathematics, Science, and Social Studies. The vital role of digital media and literacy information for developing critical thinking skills is a demanding challenge for university students and teachers (Sari & Aminatun, 2021), (Xu, 2018), (Yulian, 2021), (Songsil et al., 2019), (Mahdi et al., 2020b), (Hirai et al., 2022a), (Yaki, 2022), (Mafarja et al., 2022).
4	Assessing teachers' effectiveness in teaching critical thinking (Songsil et al., 2019).
5	Developing an instrument to measure student's critical thinking skills (Basri et al., 2019).
6	Design of suitable programs and modules to further meet the learning needs of the students related to CTS (Song et al., 2020b).
7	Researchers should consider larger sample sizes to yield more impactful outcomes in their studies aimed at fostering students' critical thinking skills. This approach will contribute to the improvement of education quality and the overall enhancement of higher education institutions (Mahdi et al., 2020).
8	Teachers should carry out empirical research on critical thinking skills (Wang, 2021).
9	Devise pedagogical approaches to enhance students´ critical thinking abilities (Wang, 2021).
10	Education institutions and students must work together to enhance graduates' acquisition of critical thinking and problem-solving skills through modifying teaching strategies and strengthening academic programs and other intervention programs.
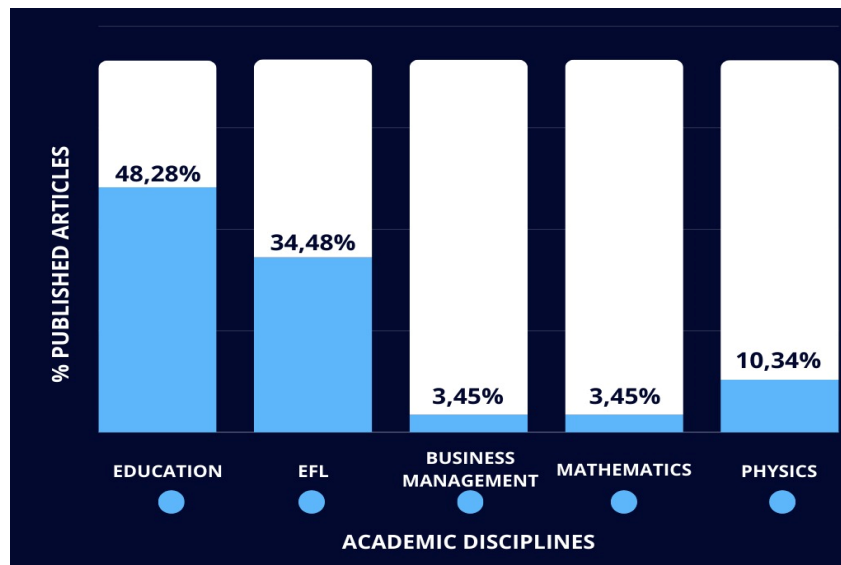
Figure 3. Percentage of CTS studies performed in academic disciplines.

Data in figure 3 states that most of the studies on CTS of students are carried out with different educative levels students. Some articles focused on EFL students and a few ones on Physics, Business Management and Mathematics students. Thus, research on analyzing CTS in all academic disciplines should be accomplished in order to help students to develop CTS and be able to propose innovate and creative solutions to real-life problems related to their professional careers.
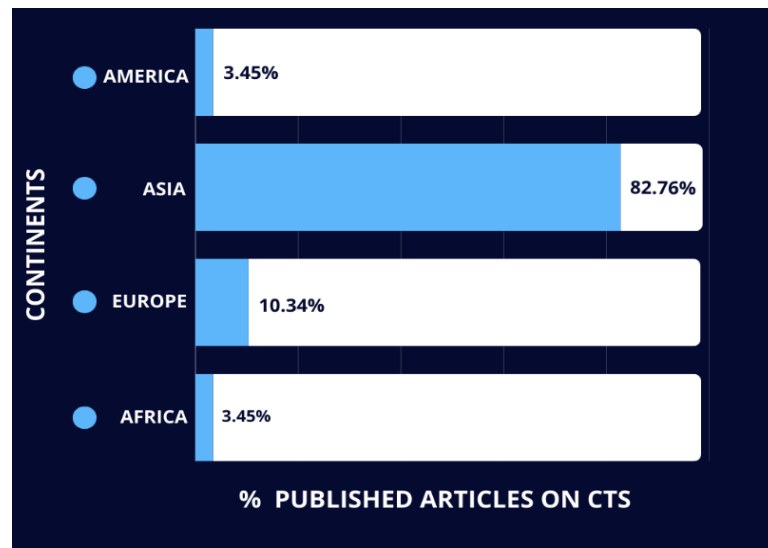
Figure 4. Percentage of CTS articles published per continent

Asian countries are greatly concerned about studying critical thinking (as shown in figure 4) due to it allows human beings to analyze data broadly, identify hidden ideas and inaccurate information. Critical thinking leads students to study regional issues solve professional problems in real-life situations and met the needs of modern society. Also, researchers consider that it is not true that critical thinking is included in the curricula of all academic disciplines, therefore, it must be developed through different methods. (Khlyzova, 2022).

Table 3 *Future research directions*

ITEM	DESCRIPTION
1	Investigate the degree and method by which students internalize the taught CTS and the effectiveness of different internalization approaches. Furthermore, it is important to consider questions related to teachers and students' perceptions [23]
2	Research on teaching strategies for CTS is necessary to examine the criteria from the viewpoint of teachers and administrators.
3	Analyze if there are gender differences in the development of critical thinking subskills among male and female students [24].
4	Examine the scientific process skills as a means to cultivate critical thinking abilities, empowering researchers to elevate the quality, rigor, and impact of their research endeavors. [25]
5	Exploring critical thinking skills in the age of Artificial Intelligence, perceptions, benefits, and limitations [26].

Proposal for making up a new test to measure critical thinking skills according to the Ecuadorian educational context.

Critical thinking is a skill that turns out to be essential in student development to face the daily challenges of their life) to such an extent that its processing depends directly on the maturity of each individual, the range of analysis or organization and reasoning or argumentation being preponderant, to finally make decisions regarding the situation or problem (López, et., 2022), (Bezanilla-Albisua et al., 2018).

Several experts consider that critical thinking is permeated throughout life and is attributed to the predisposition of the human phenomenon to think (Roca, J., 2014). The indicated dimensions of this reasoning are directly linked since they require a particular point of view to recognize a question based on prior information and, with a particular intention, reveal answers that involve both implications and consequences (Roca, J., 2014). So, according to several theorists, there are points of convergence in the moments of the production of critical thinking; in education, we must include a first moment of entry of sensory information, one of analysis, and a final stage of judgment or decision.

Critical thinking has a higher order since its direct relationship with the logical need to understand is bound to cognitive abilities. In addition, its constant use activates an active reception of ideas and the acquisition of deep knowledge and thought development (Riascos, M., 2022). Cognitive abilities allow us to solve problems and incorporate a variety of competencies and abilities to apply procedures that can be used to innovate, improve, and reach resolutions (Rivas et al., 2023). Thus, it is possible to make up a proposal that includes advances in computer science and neuroscience on using neural capacities and networks to use thought, its function, and anticipation in tasks of a different nature. Also, it is advisable to tailor an instrument that assumes brain function as the basis for predicting human behavior and thought. Then, it will make up a product that understands, explains, and develops critical thinking in the higher education population and the scientific community. It could be an excellent contribution to scientific research processes at universities.

To complement our proposal, cognitive functions and human aspects play significant roles in the development and execution of research skills. Research is a complex and multifaceted process that involves gathering, analyzing, and interpreting information to generate new knowledge or insights.

Cognitive functions provide the intellectual tools necessary for rigorous and systematic investigation, while human aspects contribute to the motivation, ethics, interpersonal skills, and adaptability required for successful research. A well-rounded researcher combines cognitive abilities with these human aspects to navigate the complexities of the research process and contribute meaningfully to their field. Figure 1 illustrates the interrelationship between research skills, particularly critical thinking competencies, stimulated by human factors and cognitive functions, as part of our proposal.

By having a direct relationship with reason, critical thinking is focused on action, and through decision-making, it reaches problem-solving. Its development allows the construction of better alternatives, thus being the key to success in all areas (Chimoy, L. 2022). In Table 4, the projected phases of our proposal are listed, which will lead to a new measurement instrument to help stimulate critical thinking as a research competence.

Table 4. *Phases of the proposal to measure CTS*

Phases	Description
Initiation	Recognition, argumentation, analysis, hypothesis, facet identification.
Inference	Cognition, interpretation, inference, synthesis, deduction, argument evaluation, cognitive tendencies, assumption.
Assumption	Decision, resolution, deduction, choice, issuance of judgments, making decisions.

From the perspective of other authors, thought, as an element of the construction of the psyche or mind, contains its production of the subject's cognitive, emotional, and experiential aspects. For example, solving problems in a research proposal cannot be dissociated from our ethics and empathy concerning the social standards built and accepted by a group. These will influence placing idealized limits (i.e., part of the production of thought) to their decisions. Here, we could mark thought as the etiology of an emotion. However, we also know that emotions can cause thinking and cognitive biases, as in the case of pathological subjects studied in clinical settings.

We propose as a basis for critical thinking the initiation of the process, an interference phase, and a decision phase, a model very close to that of memory, which takes storage, encoding, and retrieval elements as a reference, processes that, in a simplified way can explain some cognitive processes and emotional.

The interpretation of the events of reality is diverse. Here lies the main element of thought. The subjectivity of its production makes it necessary for each subject to analyze what goes through its mind when faced with a stimulus and how it labels or stores it. There is a direct relationship to this linking of thought and emotion in the phases of our proposal.

As suggested, emotional levels influence how our thought organizes emotion, ranks, and is exposed to the outside.

The researcher cannot dissolve or dissociate these elements, which have marked the evolution of man as a species.

Emotions, by feeding on physiological elements of subcortical structures of the brain, such as the limbic system and fully differentiated areas, create sensitive reactions. These will be the basis of our research proposal so that after a sensory input (emotional in its various manifestations), we can develop thoughts of affiliation to-wards the research culture in the students.

Critical and rational thinking typical of science will be the one that we propose to develop, and with it, all the cognitive abilities and that of the emotional system can be detached.

Crosswise, we will also undoubtedly find cognitive or thought biases (i.e., influenced by emotions) that make it difficult for students to produce critical thinking. This drives the need to create a new measurement and interpretation tool for this element. Likewise, it will be the input for designing and implementing an instrument, software program, or platform that seeks the convergence between emotions, thought, and decision-making in students searching for answers to social and educational phenomena with scientific research.

CONCLUSIONS

Critical thinking has gained significant attention in education systems worldwide, as it is a skill that plays a crucial role in scientific research. In addition, it equips students to address a wide range of challenges arising from economic, social, environmental, health, technological, and geopolitical factors.

Critical thinking goes beyond traditional knowledge and is essential for navigating complex issues successfully. Those with strong critical thinking abilities can objectively analyze information, evaluate situations from multiple perspectives, and make well-informed decisions. Beyond academic excellence, critical thinking plays a crucial role in professional success and employability, as employers highly value candidates who can effectively solve problems, adapt to changes, and contribute innovative ideas. Critical thinking is recognized as a vital skill in the 21st century.

Recent research has identified several critical thinking competencies, including analysis, argumentation, interpretation, evaluation, inference, explanation, and self-regulation. While these have been extensively studied, other critical thinking subskills still warrant further investigation.

Various methodologies have been employed to foster students' critical thinking skills, such as reciprocal teaching, flipped classroom, STEM education, case studies, problem-solving, instructional pedagogy, and Bloom's Taxonomy questions across different educational levels globally, cooperative based learning model (CAP-based learning model) and multiple intelligence-based differential learning. Most of them improve students´ critical thinking skills. There are a few tries to make up methods to develop scientific research skills, but all of them are based on the scientific research method.

Although it was expected to find a new and wide variety of CTS tests, there were identified the following instruments: PENCRISAL, CLA+International Test, RASCH inventory, CTS scale and CLA+International Test. Specific tests to measure scientific research skills were not found. Several tests are tailored on the basis of the CCTST and the Watson Glaser Critical Thinking Test.

Educators, policymakers, parents, and governments face challenges in implementing practical approaches to developing critical thinking, designing relevant curricula, providing educational resources, and offering critical thinking training for teachers. Additionally, more attention should be paid on studying CTS in all academic areas, not only in Education and EFL. Research on CTS must be the influence of gender on critical thinking needs to be explored further.

Research on CTS in all academic disciplines is a must that higher education institutions should primarily include in their research plans.

Higher-education institutions from all the continents must broad research on CTS since it is one of the most relevant scientific research skills. Data showed that almost all the articles published on CTS are produced in Asia

Future research directions should focus on creating new measurement instruments for critical thinking subskills and exploring novel strategies to enhance their use in scientific research. One crucial area of concern is developing a new critical thinking test tailored for diagnosing the critical thinking abilities of higher education students when they carry out research projects. By addressing these challenges and pursuing further research, we can continue to foster critical thinking capabilities among students, preparing them for success in an ever-changing world.

REFERENCES

Alhamuddin, A., Inten, D.N., Mulyani, D., Suganda, A.D., Juhji, J., Prachagool, V., & Nuangchalerm, P. Multiple intelligence-based differential learning on critical thinking skills of higher education students. International Journal of Advanced and applied Sciences. 2023, 10, 132-139. https://doi.org/10.21833/ijaas.2023.08.015

Al-Rahbi, A.M.; Al-Mekhlafi, A.M.; Al-Barwani, T.; Omara, E. Challenging the Status Quo: Critical Thinking Skills Integration in the EFL Curriculum of Young Learners. Journal of Curriculum and Teaching 2022, 11, 79. https://doi.org/10.5430/jct.v11n8p79.

Araque Escalona, J. C., Rivas Urrego, G., & Urrego, A. J. (2020). Paulo Freire y el pensamiento crítico: Palabra y acción en la pedagogía universitaria. Revista Educare, 24(2). https://revistas.investigacion-upelipb.com/index.php/educare/article/view/1331/1319

Barrera Mendoza, M. P., López Mendoza, M., Moreno, E. M., & Uyaguari Flores, J. (2022). El desarrollo del pensamiento crítico en el aula: testimonios de docentes ecuatorianos de excelencia. Areté Revista Digital del Doctorado en Educación de la Universidad Central de Venezuela, 8(15), 161-180. https://doi.org/https://doi.org/10.55560/ARETE.2022.15.8.8

Basri, H.; Purwanto, P.; As'ari, A.R.; Sisworo, S. Investigating Critical Thinking Skill of Junior High School in Solving Mathematical Problem. International Journal of Instruction 2019, 12, 745–758. https://doi.org/10.29333/iji.2019.12345a.

Bezanilla-Albisua, M.J.; Poblete-Ruiz, M.; Fernández-Nogueira, D.; Arranz-Turnes, S.; Campo-Carrasco, L. El Pensamiento Crítico 525 desde la Perspectiva de los Docentes Universitarios. Estudios pedagógicos (Valdivia) 2018, 44, 89–113. https://doi.org/10.4067/s0 526 718-07052018000100089.

Chen, C.; Zhe, C.; Zheng, Y.; Xiong, X.; Xiao, T.; Lu, X. Evaluation of Scientific Research in Universities Based on the Theories for Sustainable Competitive Advantage. SAGE Open 2023, 13, 215824402311770. https://doi.org/10.1177/21582440231177048.

Chimoy Lenz, E., Gonzaga Contreras, R., & Linares Mallap, W. N. (2022). Critical Thinking in the 21st century educational system. Scientific Journal Hacedor - AIAPAEC, 6(1), 65-79. https://doi.org/https://doi.org/10.26495/rch.v6i1.2117

Darmaji, D.; Astalini, A.; Kurniawan, D.; Setiya, E. Gender analysis in measurement materials: Critical thinking ability and science processing skills. Journal Ilmiah Pendidikan Fisika Al-Biruni 2022, 11, 113–128.

Darwin.; Rusdin, D.; Mukminatien, N.; Suryati, N.; Laksmi, E.D.; Marzuki. Critical thinking in the AI era: An exploration of EFL students' perceptions, benefits, and limitations. Cogent Education 2023, 11. https://doi.org/10.1080/2331186x.2023.2290342.

Esparrago, A.J.H. Categories of Questions and Critical Thinking. Journal of Innovations in Teaching and Learning 2021, 1, 107–116.

Ghaani, M.; Pauline Roslin, V. A Study on the Knowledge, Attitude, and Practice of Critical Thinking Skills among EFL Teachers in Iran. KURMANJ The Journal of Culture Humanities and Social Science 2021. https://doi.org/10.47176/kurmanj.3.2.14.

Hirai, A.; Oka, H.; Kato, T.; Maeda, H. Development and validation of an English test measuring EFL learners' critical thinking skills. Language Testing in Asia 2022, 12. https://doi.org/10.1186/s40468-022-00193-2.

Hye, Q. M. A., Iram, U., & Hye, A. (2009). Exchange Rate and Trade: A Causality Analysis for Pakistan Economy. IUP Journal of Applied Economics, 8(5/6), 161.

Joy B. Wong, E.; Dave R. Montero, J.; M. Escala, K.; F. Banayo, A. Implementation of Soft Skill-Based Metacognitive Approach in Improving the Critical Thinking Skills of Pre-Service Teachers. International Journal of Research Publications 2022, https://doi.org/10.47119/ijrp1001071820223779.

Khlyzova1, N.; Scientific approaches to developing critical thinking in Asian-Pacific region. SHS Web of Conferences 134, 00174 (2022). https://doi.org/10.1051/shsconf/202213400174

Kitchenham, B.; Pearl Brereton, O.; Budgen, D.; Turner, M.; Bailey, J.; Linkman, S. Systematic literature reviews in software engineering – A systematic literature review. Information and Software Technology 2009, 51, 7–15. https://doi.org/10.1016/j.infsof.2008.09.009.

Jam, F. A., Singh, S. K. G., Ng, B., & Aziz, N. (2016). Interactive effects of Gender and Leadership Styles on Open Service Innovation: A Study of Malaysian Doctors, International Journal of Economics Research, 13(3), 1287-1304.

Lee, M.F.; Mohd Sohod, S.N.; Ab Rahman, A. Exploring the Mastery Level of Critical Thinking and Problem Solving Skill among the Technical Undergraduate. Journal of Technical Education and Training 2019, 11. https://doi.org/10.30880/jtet.2019.11.03.002.

Mahdi, O.R.; Nassar, I.A.; Almuslamani, H.A. The Role of Using Case Studies Method in Improving Students' Critical Thinking Skills in Higher Education. International Journal of Higher Education 2020, 9, 297. https://doi.org/10.5430/ijhe.v9n2p297.

Mohammadi, M.; Abbasian, G.R.; Siyyari, M. Adaptation and validation of a critical thinking scale to measure the 3D critical thinking ability of EFL readers. Language Testing in Asia 2022, 12. https://doi.org/10.1186/s40468-022-00173-6.

Morales Riascos, M. (2022). Desarrollo de elementos del pensamiento crítico y su intervención en la enseñanza de la química en educación secundaria y media. Red Laecin Revista Latinoamericana de Educación Científica Crítica y Emancipadora, 116-135. https://www.revistaladecin.com/index.php/LadECiN/article/view/29/7

Noroozi, O. The role of students' epistemic beliefs for their argumentation performance in higher education. Innovations in Education and Teaching International 2022, 60, 501–512. https://doi.org/10.1080/14703297.2022.2092188.

Poštic´, S.; Kriaucˇiu¯nenie˙, R.; Ivancu, O. Viewpoints on the Development of Critical Thinking Skills in the Process of Foreign 470 Language Teaching in Higher Education and the Labor Market. Education Sciences 2023, 13, 152. https://doi.org/10.3390/ 471 educsci13020152.

Rizki, I.; Suprapto, N.; Saphira, H.; Alfarizy, Y.; Ramadani, R.; Saputri, A.; Suryani, D. Cooperative model, digital game, and augmented reality-based learning to enhance students' critical thinking skills and learning motivation. Journal of Pedagogical Research. 2024, 8, 339-351. https://doi.org/10.33902/JPR.202423825

Roca Llobet, J. (2013). El desarrollo del Pensamiento Crítico a través de diferentes metodologías docentes en el Grado en Enfermería. Bellaterra: Universitat Autónoma de Barcelona. https://www.tesisenred.net/bitstream/handle/10803/129382/jrl1de1.pdf

Sari, Y.P.; Aminatun, T. Analysis of Critical Thinking Skills on Implementation of Problem-Based Learning on Endemic Flora and Fauna in Senior High School in Bengkulu. In Proceedings of the Proceedings of the 6th International Seminar on Science Education (ISSE 2020). Atlantis Press, 2021, isse-20. https://doi.org/10.2991/assehr.k.210326.018.

Song, B.K.; Lim, L.Y.; Rengiah, S. The Development and Validation of a Critical Thinking Skills Inventory: RASCH and Confirmatory Factor Analysis Approaches. SSRN Electronic Journal 2020. https://doi.org/10.2139/ssrn.3571365.

Songsil, W.; Pongsophon, P.; Boonsoong, B.; Clarke, A. Developing scientific argumentation strategies using revised argument-driven inquiry (rADI) in science classrooms in Thailand. Asia-Pacific Science Education 2019, 5. https://doi.org/10.1186/s41029-019-0035-x.

Vázquez-Villegas, P.; Mejía-Manzano, L.A.; Sánchez-Rangel, J.C.; Membrillo-Hernández, J. Scientific Method's Application Contexts for the Development and Evaluation of Research Skills in Higher-Education Learners. Education Sciences 2023, 13, 62. https://doi.org/10.3390/educsci13010062.

Wang, L. Critical Thinking Sub-Skills in English Debate. Theory and Practice in Language Studies 2021, 11, 1630–1635. https: 488//doi.org/10.17507/tpls.1112.15.

Xu, S. An Exploration into Chinese EFL Students Critical Thinking. In Proceedings of the Proceedings of the 2018 8th International Conference on Social science and Education Research (SSER 2018). Atlantis Press, 2018, sser-18. https://doi.org/10.2991/sser-18.2018.159.

Yaki, A.A. Fostering Critical Thinking Skills Using Integrated STEM Approach among Secondary School Biology Students. European Journal of STEM Education 2022, 7, 06. https://doi.org/10.20897/ejsteme/12481.

Yulian, R. The flipped classroom: Improving critical thinking for critical reading of EFL learners in higher education. Studies in English Language and Education 2021, 8, 508–522. https://doi.org/10.24815/siele.v8i2.18366.

Zulnaidi, H.; Mafarja, N.; Mohd. Fadzil, H. Using Reciprocal Teaching Strategy to Improve Physics Students' Critical Thinking Ability. Eurasia Journal of Mathematics, Science and Technology Education 2022, 18, em2069. https://doi.org/10.29333/ejmste/11506.