

# Quantitative Reasoning is a Key Factor for High School Students

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**Abstracts:** The present study aimed to analyze the process of development of quantitative reasoning in high school students. A literature review study was applied through a content analysis, performing a search in the databases a) Scopus, b) SciELO, c) Dialnet, d) Latindex and e) Google Academic, using as keywords: a) quantitative reasoning b) secondary education students, c) quantitative literacy, d) pedagogical practice, e) teaching/learning and selecting through a sampling based on the following criteria: a) original scientific articles or review, b) publications in Spanish or English, c) time period between the first and the second year of the study. 2015-2023, d) undergraduate these included in institutional repositories and e) citable documents, allowing to discriminate a total of 40 articles to be reviewed. The analysis of the texts made it possible to identify three categories of analysis a) Quantitative reasoning opening paths for the development of systematic thinking, b) Language and literature essential elements for the development of quantitative reasoning and c) The role of Information and Communication Technologies (TIC) in the development of quantitative reasoning, concluding that quantitative reasoning helps students to learn to properly use and evaluate quantitative information and build arguments.

**Keywords:** Quantitative Reasoning, Students, Secondary Education, Meaningful Learning, Pedagogical Practice.

## 1. INTRODUCTION

Since time immemorial, education has been the backbone of human development, and educational institutions have become crucial nodes in the chain connecting social progress with the production of knowledge. This is because, in addition to their traditional focus on citizenship education, modern educational institutions seek to address society's most pressing problems. In today's world, driven by the transformations generated by the realities arising from globalization, educational institutes must provide a multifaceted curriculum that equips students in training with the necessary skills to face everyday challenges (Carvajal Sánchez, 2017).

In this sense, it is pertinent to refer to what is known as quantitative reasoning (RC) or quantitative literacy, which, according to Cervantes Campo et al. (2022), allows understanding, analysis, argumentation and decision making to solve problems based on information that lend themselves to numerical representation, therefore, all people should have the ability to face and solve generic mathematical problems, which may arise in any context. It is also worth mentioning Ricra Mayorca (2022) who defines it as a process of analysis in which students, in addition to solving problems, support their statements through an argumentative process, thus promoting the achievement of meaningful learning. As a result, it is important to recognize that this constitutes a crucial part of the learning experience of students, because mathematical knowledge and skills provide learners with the necessary resources to assume an active and informed role in society, in a wide range of spheres, including social, cultural, educational, among others (Mendoza et al., 2021).

Reason why, authors such as Cervantes Campo et al. (2022) point out that all students, regardless of the educational level they are in, need a certain level of CR skills to function effectively in everyday situations involving

quantitative data and these are:

a) Interpretation and Representation: this skill requires not only the ability to understand individual data elements, but also the flexibility to construct diverse representations of these data. In other words, it relates the data to its meaning and context within the problem, contrasting the many ways in which it can be represented, as well as other skills such as understanding and manipulating data through a variety of formats and representations.

b) Formulation and Implementation: The processes associated with problem identification, strategy proposal and implementation are part of this skill set, and the modeling and use of quantitative resources (which includes arithmetic, geometry, elementary algebra, probability and statistics). Specifically, assessing performance in areas such as devising appropriate processes and strategies to deal with a situation, choosing the right data and determining the right variables to solve a problem, ideas multiple plans, strategies and options for doing so, making use of quantitative tools, and successfully solving problems that have been presented.

c) Argumentation: The ability to argue encompasses all the steps used to ensure that certain statements are true, such as providing evidence to support or refute interpretations and models of a given situation. That is, assessing performance indicators such as the ability to defend the choice of mathematical techniques and strategies to solve problems and to base arguments on mathematical properties and concepts.

Hence, it is important to pay close attention to the development of these skills, taking into account the procedures that allow the student to advance the degree of mathematical complexity and thus achieve meaningful learning, rather than just memorizing procedures. With this in mind, Rahim et al. (2020) argue that the main objective in learning to solve problems should be the main focus of mathematics education, which is not limited to providing a number or magnitude after applying certain formulas, but goes beyond, it involves understanding the real problem you are trying to solve and how to address it in broader social or conceptual contexts, requires careful reflection and reasoning about the relevance of the mathematical methods selected and applied for this purpose, as well as the correct interpretation of the results (Espinoza, 2017). Seen in this way, CR becomes a formulated line of reasoning, and instruction from this perspective allows students to achieve a satisfactory result in their educational process.

Having said the above, it is pertinent to state that CR creates a framework for action that aims to solve problems or improve situations, but also seeks to strengthen students' reasoning and knowledge to foster greater understanding and skill development, producing a fully functioning citizen who makes significant contributions to humanity and to the institution itself.

Recognizing the importance of CR in the educational process, the following question emerged: How is the CR process in high school students? For this reason, the objective of the study was to analyze the process of CR development in secondary school students.

## **2. MATERIEL AND METHODS**

The present literature review study, allows revealing the importance of the topic by collecting information available in previously published resources, by collecting all the evidence that satisfied the eligibility criteria established to address the topic of scientific research (Sobrido Prieto & Rumbo-Prieto, 2018), using content analysis as a research technique, which is a method used to perform an objective description, systematic and quantitative description of the content expressed in communication, but which also has qualitative implications, as in the present study, which seeks to decipher the hidden meaning found in the texts through a process of searching for meaning and classification, which allows any bias introduced by the researcher's own subjective perspective to be significantly diminished.

This began with keyword recognition, which according to Granda et al. (2003) is crucial for the process of identifying publications available in databases. For the purposes of this study, the search terms were derived from the inclusion of the following keywords: a) quantitative reasoning b) secondary education students, c) quantitative

literacy, d) pedagogical practice, e) teaching/learning, combining among them the use of the Boolean "AND", these accompanied the search of the works that were considered for the research, identifying studies that explored each category and included in the scope of publications considered frontier studies, due to their novelty and new approach to the topic of interest.

The search terms described above were processed through the following databases: a) SciELO, b) Dialnet, c) Latindex and d) Google Scholar, which yielded a total of 126 documents (n = 126). From these, a selection of relevant texts was made based on predetermined criteria (Herbas & Rocha, 2018), which delimited the search, being the following: (a) original or review scientific articles, (b) publications in Spanish or English, (c) time period between 2015-2023, (d) degree these included in institutional repositories and (e) citable documents, while those for exclusion were; (a) opinion articles, (b) published in language other than English or Spanish, (c) prior to 2016, all of which led to the selection of forty (n = 40) publications to review, as described in Table 1.

**Table 1 Research according to the search engines used**

Scopus	SciELO	Dialnet	Latindex	Google Académico	Total
12	10	6	1	11	40

The selected literature was processed using the bibliographic record technique, with the aim of compiling and organizing the relevant information implicit in it, and the content analysis was refined by using craft techniques for the identification of frequent words within the text, supported by the use of digital tools for this purpose.

### 3. RESULTS AND DISCUSSIONS

Table 2 shows the corpus of documents that was retrieved and selected for the progress of this study, in accordance with the edges of the research topic.

**Table 2 Coherence matrix between the reviewed papers and the study categories**

Category	Author(s)
Quantitative reasoning opening paths for the development of systems thinking	Alejo (2022); Bethancourth Zambrano et al. (2017); Cervantes Campo et al. (2022); Espeleta et al. (2020); Esquivel et al. (2022); Vera Rodríguez (2020); Cárdenas Vallejo et a. (2015); Aguilar-Pérez et al. (2022); Ortiz Armero (2022); Durán (2019); Morales-Martínez (2022); Castro (2022); Nuñez-Lira (2020); Herrera Briñez (2017); Lluén Muga (2019); Moreira Sánchez (2019); Martínez Suárez (2022); Villamizar Jaimes et al. (2021); Astaíza Martínez et al. (2022); Romero-Carazas et al. (2023)
Language and Mathematics pivots for the development of quantitative reasoning	León et al. (2018); Salvatierra Melgar et al. (2019); Cervantes Campo et al. (2022); Borda et al. (2021); Echeverri Quintero (2019); Unigarro-Gutiérrez et al. (2018); Álvarez (2020); Muñoz-Muñoz et al. (2017); Barboza (2021); Velasco-Moreira et al. (2021); Soto et al. (2019)
The role of ICT in the development of quantitative reasoning	Vergara Jiménez et al. (2015); Semanate-Semanate et al. (2021); Lizarazo Gómez (2020); Broda et al. (2021); Barrera-Mora et al. (2018); Medina (2019); Ricra Mayorca (2022); De Cacheiro González (2018); Villamizar Jaimes (2021); Rodríguez Gaona (2022); Ximena et al. (2022); Rodríguez-Revilla et al. (2022)

Figure 1 shows the key terms that emerged from the analysis of the scientific resources that guided the development of the analytical units of the research, and that helped in the construction of the categories: a) Quantitative reasoning opening ways for the development of systematic thinking b) Language and literature essential elements for the development of quantitative reasoning and c) The role of ICT in the development of quantitative reasoning.



**Figure 1.** Words with greater repetition in the texts reviewed.

The following is an analysis of the elements implicit in the literature reviewed on CR in high school students, based on the determination of the three categories constructed: a) Quantitative Reasoning opening ways for the development of systematic thinking b) Language and literature essential elements for the development of Quantitative Reasoning and c) The role of ICT in the development of quantitative reasoning.

### 3.1. Quantitative Reasoning Opening Pathways For The Development Of Systematic Thinking

CR plays a key role in the development of systematic thinking in secondary school students, as this skill enables them to understand, analyze, and use numerical information effectively in a variety of situations. Systematic thinking involves the ability to organize and structure knowledge, identify patterns and relationships, formulate hypotheses, and make evidence-based decisions. Thus, CR provides students with the necessary tools to develop these skills and apply them in their academic life and beyond (Alejo, 2022).

Thus, it is understood that CR constitutes a cornerstone of education, starting from mathematical problem solving, and students who master this set of skills are better prepared to handle the challenges of everyday life. This is because CR is one of the central components of education, and its development is crucial to establish a foundation for quantitative learning (Betancourth Zambrano et al., 2017; Cervantes Campo et al., 2022).

In this sense, it is important to understand that CR, provides students with the resources they need to face present and future challenges. Given this, it is clear that the incorporation of this type of method in secondary education will help students to contextualize their knowledge in light of the daily challenges they will face (Espeleta & Valverde, 2020).

It is worth noting that CR is emerging as a viable alternative to teach students to think systematically in light of the changing demands of a rapidly globalizing and technologically advancing digital world (Esquivel et al., 2022; Vera Rodríguez, 2020), for this reason, strengthening mathematical literacy is a crucial starting point for any academic endeavor (Cárdenas Vallejo & Cárdenas Vallejo, 2015). However, it must be understood that to achieve this, it is necessary that, starting with CR, critical thinking skills are cultivated so that students can reflect on their own learning, engage in healthy debates and ultimately achieve meaningful learning (Aguilar-Pérez et al., 2022; Ortiz Armero, 2022).

One of the key aspects of CR is the understanding of fundamental mathematical concepts. Secondary school students must acquire solid knowledge in areas such as arithmetic, algebra, geometry, statistics and probability. These concepts enable them to analyze situations in a structured way, pose problems in mathematical terms, and find accurate solutions. In addition, CR provides them with the tools to interpret and evaluate numerical information presented in tables, graphs, and other visual representations (Durán, 2019; Morales-Martínez, 2022).

Consequently, the didactic strategies that educators employ are crucial if you want your students to develop CR, a type of thinking that may include not only problem solving, but also the justification of solutions based on their own experiences (Castro, 2022; Ricra Mayorca, 2022). Therefore, these strategies should consider the actual use of ICTs as an essential means to achieve an adequate standard of living, using them as a resource to advance knowledge management (Vera Rodríguez, 2020).

The reality of the matter lies in the various strategies that an educator, in the formative process, can employ to mold critical and reflective thinking in their students (Núñez-Lira et al., 2020). As mentioned in the initial lines, this is promoted through CR, which adapts the education of students to the circumstances of everyday life (Herrera Briñez, 2017).

Thus, it should be understood that this formative process constitutes a fundamental part in the learning of learners and promoting the use of various didactic and technological strategies (Lluén Muga, 2019), constitutes the way to establish information exchange activities to strengthen the development of CR, which, will allow the learner to face the scenarios they may face in the future (Moreira Sánchez, 2019).

To this point, it is understood that the learning process under this approach promotes the formation of systematic thinking through problem-based learning (Martínez-Suárez, 2022), which leads to the acquisition of essential skills for the development of CR, whose methods facilitate the acquisition of knowledge through a dynamic and comprehensive approach (Villamizar Jaimes et al., 2021).

In this sense, learning that fosters the development of systematic thinking based on CR in secondary school students opens the door to the various possibilities they may have to promote actions that lead to real and true meaningful learning, thus ensuring success in their academic career (Astaíza Martínez et al., 2022; Romero-Carzas et al., 2023).

In general terms, it is valid to state that CR constitutes a factor of great importance in the educational process, particularly because it is a strategy aimed at fostering critical thinking through meaningful learning, whose ultimate goal is to equip learners with the tools they need to address problems in their daily lives and in the world around them, involving a complex scaffolding construct, which allows the construction of systematic thinking.

### **3.2. Language And Mathematics Pivots For The Development Of Quantitative Reasoning**

Unquestionably, all human beings throughout their lives, acquire an accumulation of mathematical knowledge that becomes second nature with experience, to the point where they can estimate without making precise calculations, these appreciations are often based on a statistical accumulation of real-world situations that the individual has encountered to his credit, it is what is called generic situations that need a CR to explain a particular situation, problem or present reality (León et al., 2018). Now, skills in mathematics become a necessity for the development of CR (Salvatierra Melgar et al., 2019), where students must be able to interpret and represent quantitative data, formulate and solve problems containing quantitative information, reason and argue about situations involving mathematical data (Cervantes Campo et al., 2022).

Because the development of CR goes far beyond arithmetic skills, it provides significant benefits such as being able to understand conceptions and determine relationships based on a logical, schematic and technical framework, whose development is fundamental for the well-being of students, implies an apparently innate competence with numerical computation, testing and formulating hypotheses (Borda & Latorre, 2021; Echeverri Quintero, 2019).

Based on what has been pointed out in the preceding lines, it should be understood that between language and mathematics a kind of indivisible relationship is formed, due to the fact that every learning process involves language, it is thus that the understanding of meaning becomes more important to successfully solve challenging situations as this process develops and to that same extent, mathematics is no different, especially if it is seen as an effort to answer problems by converting everyday language into mathematical symbols (Unigarro-Gutiérrez et al., 2018). Consequently, the first step to solve a problem, is to understand it in terms of the mathematical

conceptions and procedures involved, that, in turn, requires not only possessing mathematical knowledge, but also knowledge in terms of linguistics and semantics (Alvarez, 2020).

In this sense, it is valid to state that in addition to being a crucial skill to interpret and apply the codes and competencies that shape today's society, reading comprehension is an integral part of the development of CR through common language, as indicated by (Muñoz-Muñoz & Ocaña de Castro, 2017), understanding properly is characterized by the ability of students to use various strategies that help to understand different texts, textual intentions and the resolution of problems and various situations that are presented to them, to appropriate specific content.

For this reason, the development of CR in secondary education learners aims at the adequate interpretation of information (Barboza, 2021; Velasco-Moreira et al., 2021), with the understanding that, for quantitatively oriented writings, techniques such as reformulating the same idea in different words, filtering relevant information, focusing on the precise question or problem at hand, determining what types of elementary operations will be required, applying those operations contextually, and transforming the format of presentation of information from common language into graphs or numbers, help learners to develop reading comprehension and CR (Soto & Noboru, 2019).

In summary, an adequate treatment of language and mathematics, as a product of a cognitive process, is fundamental for the educational process of secondary education learners. That is why, from the educational scenarios, educators have the responsibility to provide instruction and design various strategies based on the use of mathematics, providing spaces for discussion, exercises to solve problems, as well as to analyze different situations, in order to provide students with as many skills as possible for the development of CR.

### **3.3. The Role Of TIC In The Development Of Quantitative Reasoning**

ICTs have slowly permeated all aspects of society, education and work environments. The main purpose of school is to provide students with the knowledge and skills they need to succeed in life and this includes fostering their scientific and technological growth (Vergara Jimenez et al., 2015). Because of this, incorporating ICT into classroom instruction is an excellent way to become familiar with their use and the understanding of these technologies by educators and learners (Semanate-Semanate & Robayo-Jácome, 2021).

Certainly, the preponderant role that ICTs have played in the educational process is unquestionable, which increased even more after the occurrence of the pandemic by COVID-19. Because they are seen as office tools that favor collaborative work inside and outside the classroom, it was evidenced that the use of ICT in education can help to enrich, change and optimize the educational path of students (Lizarazo Gómez, 2020). In fact, several technological resources allow the development of collaborative tasks in real time and facilitate educator/learner connections throughout the instructional process (Borda & Latorre, 2021).

Working with ICT, provides endless elements that are fundamental in the new spaces, including realistic and rich environments, the development of systematic thinking, the discovery of a problem, its representation, the development of metacognition and the facilitation of group interactions, therefore, its incorporation is considered a key factor in the educational process (Barrera-Mora & Reyes-Rodríguez, 2018; Medina, 2019). This finds support in the words of Ricra Mayorca (2022), when he recognizes that the use of ICT for the development of CR allows learners to participate in an enchanting and interesting world connecting technology and mathematics, also allowing them to enrich their knowledge, acquiring high levels of skill and developing systematic thinking.

Given this reality, it is understood that the inclusion of ICT as a central support tool in the educational process, ensures that students have access to an engaging and stimulating learning environment (De Cacheiro González, 2018; Medina, 2019), where they strengthen their knowledge, develop their CR skills and solve problems more effectively. ICTs, in addition to generating models, allow their visualization and the use of dynamic diagrams that students use to represent, manipulate and understand specific situations (Villamizar Jaimes, 2021).

In addition, ICTs allow students to access a wide range of online resources, such as educational videos, interactive tutorials and practical exercises. These digital resources provide students with the possibility of learning at their own pace, reviewing difficult concepts and practicing mathematical skills autonomously (Rodríguez Gaona, 2022). By enabling personalized learning, ICTs can adapt to the individual needs of each student, providing additional support to those who require more time or practice to develop their CR (Ximena et al., 2022).

ICT also fosters collaboration and interactive learning among students. Through online platforms, students can participate in group activities, solve problems together, and discuss mathematical concepts. These collaborative opportunities allow them to develop communication and critical thinking skills, while strengthening their quantitative reasoning through discussion and exchange of ideas with their peers (Rodríguez-Revilla & Vallejo-Molina, 2022).

The above lines lead to the understanding that the use of ICT as a resource for the development of CR is of great importance, therefore, the design of learning environments in which students actively seek knowledge, instead of just receiving it, as well as the creation of digital resources that facilitate this process, becomes a task that educational institutions must address, in order to provide students with the necessary tools for their comprehensive training (Romero-Carazas et al., 2023).

## CONCLUSIONS

This possibility of analysis has made it possible to establish that quantitative reasoning helps students learn to adequately evaluate quantitative information and construct arguments, while at the same time making it possible to demonstrate that mathematical argumentation, mathematical communication and problem solving are not skills that develop independently in human cognition, but rather that they are inextricably intertwined; consequently, when these skills are fully developed, the student will have a solid mental framework that will allow him/her to approach situations, understand and adapt them, solving them from the perspective of mathematics.

Quantitative reasoning, understood as the ability of students to argue, discuss, understand situations and offer alternative solutions through systematic thinking, should be one of the transversal axes in which the curricula of secondary education institutions should venture, in order to optimize the educational process of the disciples, always with a view to achieving meaningful learning and the formation of a citizen with the necessary skills to deal with any situation that arises.

Similarly, the incorporation of ICT in the instruction and learning processes, presents an opportunity for change and transformation in educational practice, by expanding the exposure of students to knowledge and skills in a methodical way, through teaching methods that direct learners towards the information of knowledge.

It is expected that the present research will constitute a meritorious support material for future studies to be carried out in the field of teaching, therefore, it is considered valuable in future prospective, to continue deepening in the developed topic, expanding the search in the databases, as well as extending the years of publication of the documents and their languages, so that studies that were discarded in the present can be included and thus a broader vision can be obtained with respect to the process of development of quantitative reasoning.

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