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Evaluation of Complex and Computational Thinking in Higher Education: A Systematic Literature Mapping from 2014 to 2024

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Abstract. In response to rapid technological advances in Higher Education, precise evaluation of Complex and Computational Thinking is essential for equipping students to address multifaceted problems and make data-driven decisions. This systematic mapping synthesized 46 peer-reviewed articles (2014–2024) from Scopus and Web of Science, applying stringent inclusion, exclusion, and quality criteria. Six key insights emerged: a) research is concentrated in the United States, France, Spain, China, and Malaysia, with Latin America, Africa, and Oceania underrepresented; b) empirical studies predominate over theoretical contributions; c) quantitative approaches, particularly ex-post-facto and experimental designs are most frequently employed to assess computational thinking, while integrative frameworks for both constructs are scarce; d) publication rates have climbed steadily since 2014, mirroring the adoption of AI-driven pedagogies and heightened emphasis on higher-order thinking skills; e) investigations focus mainly on undergraduate cohorts; (f) digital and hybrid environments dominate computational-thinking assessments, whereas complex thinking is examined across a wider array of contexts, including traditional classrooms and clinical laboratories. This review delineates current complex and computational thinking assessment practices and highlights the need for geographically diverse, theoretically balanced, and methodologically integrative research.

Keywords: complex thinking, computational thinking, educational innovation, higher education, systematic mapping.

1 Introduction

In the context of a constantly evolving digital society, the need for higher order thinking skills has intensified, particularly in educational environments. Universities are expected to prepare students not only with technical knowledge, but also with cognitive and metacognitive skills that enable them to critically address complex and dynamic problems[1]. Among these skills, Complex thinking and Computational Thinking (CCT) have gained increasing importance as essential competencies to foster innovation, adaptability, and decision making necessary in an era marked by uncertainty and technological acceleration [2, 3]. This makes it essential to establish rigorous frameworks to assess their impact on student learning and cognitive development [4, 5].

Understanding the nature of CCT is key to analyze its development and evaluation at the Higher Education (HE). Complex thinking is understood as the ability to approach reality from multiple interrelated dimensions, integrating holistic and interdisciplinary perspectives that recognize uncertainty and interdependence as constitutive parts of knowledge [6]. Its attributes, critical, scientific, systemic and innovative thinking, have been enhanced through pedagogical approaches such as blended learning and collaborative projects in real scenarios [7–9]. For its part, computational thinking involves formulating and representing problems in an automatable way, using abstraction, decomposition, pattern recognition and algorithm design, while developing creativity and logical reasoning [10–13]. In the HE setting, both in STEM degrees and in other areas of knowledge, initiatives such as programming bootcamps and computational labs have been shown to improve problem-solving skills and promote collaborative learning [14–16]. The review and conceptualization of CCT allows us to systematically explore how these competencies are assessed in the academic literature.

This study aims to analyze the scientific literature published between 2014 and 2024 on CCT assessment in HE contexts. A systematic mapping was carried out using the Scopus and Web of Science (WoS) databases, applying clear inclusion, exclusion and quality criteria to ensure the relevance of the selected studies. The literature mapping carried out identifies the geographical distribution of the studies and their citation frequency, providing a clear view of the national contexts that have contributed to the field. Also, the types of research, methodological approaches, designs, and data collection techniques employed in CCT evaluation are analyzed [17–20]. An examination of the temporal evolution of the academic production on this topic is made, as well as an analysis of the academic context and disciplinary area in which the studies included in this review are developed, in accordance with UNESCO's ISCED-F 2013 [21]. Finally, a description of the educational environments and technological supports used is made, which allows us to identify which infrastructures favor or limit the assessment of these skills [22–25]. The results provide an overview of how CCT has been evaluated, the contexts in which such evaluation is conducted, and the methodologies employed.

2 Research Methodology

A systematic literature mapping was chosen for this research. This type of study consists of a broad review of primary studies in a specific subject area to determine the available evidence [26]. According to [27] the review process has three main phases: planning, execution, and reporting. To develop an SLR study in the future, it is essential to conduct a preliminary analysis of the research area of interest, and in this sense, a systematic literature mapping study represents the first step in the procedure.

2.1 Planning

The first phase described in this systematic literature mapping involved planning the study. The topic to be investigated, "Evaluation of CCT in HE" has recent data, and no systematic mappings or SLRs were found. Therefore, the need for a systematic mapping was identified to obtain an overview of the topic. Table 1 presents the research questions guiding this study; the full table, including all response options, can be accessed via the following link: https://doi.org/10.5281/zenodo.15636834. The inclusion and exclusion criteria were established to specify the limits and scope of the present study (see Table 2). Studies published from 2014 onward were included to have the most recent scientific production.

Table 1. Research questions

Research Questions
RQ1 What is the geographical distribution of studies on the assessment of CCT in HE?
RQ2 What types of research, methodological approaches and designs are used in studies that assess CCT in HE?
RQ3 How has the academic production on the assessment of CCT in HE evolved over time?
RQ4 What is the university academic context and disciplinary area of the study?
RQ5 What type of educational environment or technological support is used in studies that address the assessment of CCT in HE?

Table 2. Inclusion and exclusion criteria

Inclusion criteria	**Exclusion criteria**
• Scientific articles/review articles, conference papers, books/ book chapter.	• Not scientific articles/studies; Conference papers, books, book chapters.
• Articles found in Scopus and WoS databases.	• Articles not found in Scopus and WoS databases.
• Articles published from 2014 to April 09th, 2025.	• Articles before 2010 and after April 09th, 2025.

• Articles published in High-Impact journals.	• Articles not published in High-Impact journals.
• Articles related to CCT in HE.	• Articles not related to CCT in HE.

2.2 Conducting

The second phase of this systematic literature mapping involved searching for articles in databases that ensured access to a journal with a high impact factor (i.e., Scopus and WoS). To establish more specific search terms, we selected keywords from several previously read articles to identify commonly used concepts. In addition, we applied the previously established inclusion criteria regarding the type of studies and their time range (from 2014 to April 2025). Table 3 shows the search string in both databases.

Table 3. Scopus and WoS search chains

Scopus search chain:
(TITLE-ABS-KEY (complex* OR "complex thinking" OR "critical thinking" OR "systemic thinking" OR "innovative thinking" OR "scientific thinking") AND TITLE-ABS-KEY ("computational thinking") AND TITLE-ABS-KEY (assess* OR evaluat*) AND TITLE-ABS-KEY ("higher education" OR university)) AND PUBYEAR > 2013
WoS search chain:
(((TS=(Complex* OR "complex thinking" OR “critical thinking” OR “systemic thinking” OR “innovative thinking” OR “scientific thinking”)) AND TS=(computational thinking)) AND TS=(assess* OR evaluat*)) AND TS=("higher education" OR university)

In this step, the search and extraction of articles were downloaded into an Excel sheet. The database search produced 50 Scopus and 90 WoS results. After removing duplicates, the Scopus database still had 50, but WOS was reduced to 59 articles. 15 studies from this list were discarded because it was impossible to access their reading for review. Also, four other articles were excluded because they were in a language other than English and Spanish, the languages of the authors of the present study. Finally, 48 more articles were excluded because they were not related to the assessment of CCT skills *per se* and were outside the subject of the present mapping. In the end, the total database consisted of 42 articles.

3 Results

The methodological mapping created an Excel database with the articles and metadata necessary to answer the research questions. Access to the database is available at https://doi.org/10.5281/zenodo.15636371

RQ1: What is the geographical distribution of studies on the assessment of CCT in HE?

The geographical distribution of the studies was analyze aiming to identify the countries that have shown the greatest scientific production in the evaluation of CCT in HE. This dimension makes it possible to recognize the focal points of academic and institutional development that led research in this field, as well as to detect regions with less representation, which is key to establishing opportunities for international cooperation and the generation of situated knowledge (see Figure 1).

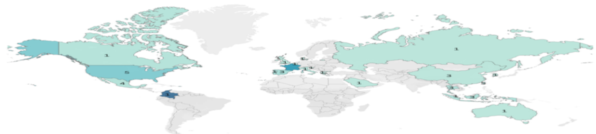

Fig. 1. Authors' geographical location.

The results show a significant concentration of studies in countries such as the United States, France, Spain, China and Malaysia, reflecting greater institutional interest in incorporating and assessing CCT in HE. Western Europe and East and Southeast Asia appear as particularly active regions, while Latin America, Africa and Oceania show more limited participation. This asymmetry suggests the need to strengthen scientific collaboration networks and funding strategies that promote research in less represented contexts.

RQ2: What types of research, methodological approaches, and designs are used in studies that assess CCT in HE?

The research type, source database, and document type allowed to visualize the contribution of each database to the academic corpus, the nature of the research approaches being prioritized, and the prevailing formats through which such studies are disseminated (see Figure 2).

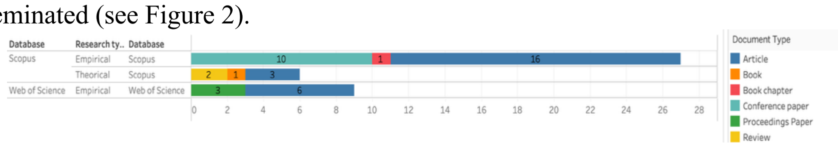

Fig. 2. Types of research in Scopus and WoS

The results show that journal articles are the preferred medium of dissemination towards formal, peer-reviewed knowledge production in this field. Building on these findings, the methodological landscape of the selected studies was examined through a classification based on research type and designs applied; to enrich the analysis, each study was also cross-referenced with the type of cognitive skills assessed. This layered categorization provides a more nuanced view of how the assessment of CCT competencies has been addressed in HE literature and reveals whether certain methodological designs tend to be associated with one type of thinking over the other (see Figure 3).

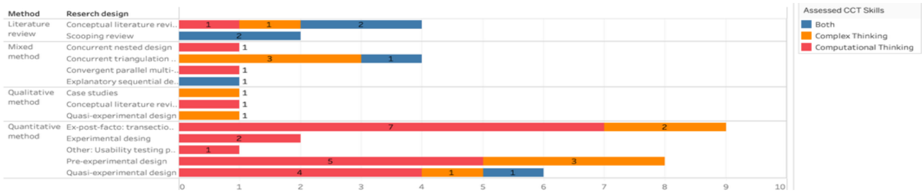

Fig. 3. Methodological approaches and research designs

The data reveals a predominant use of quantitative methods, especially in the form of ex-post-facto and pre-experimental designs, largely oriented toward the evaluation of computational thinking. Qualitative approaches, such as case studies and conceptual literature reviews, are far less represented, while mixed methods appear mostly in triangulation or nested designs that favor complex thinking. Notably, very few studies integrate both types of thinking within the same methodological framework, highlighting a fragmentation in the current research paradigm.

RQ3: How has the academic production on the assessment of CCT in HE evolved over time?

The distribution of publications over time was examined to identify key moments of growth or stagnation in academic production, as well as possible correlations with emerging techno-pedagogical trends; to this end, the studies were classified according to the type of competency evaluated (see Figure 4).

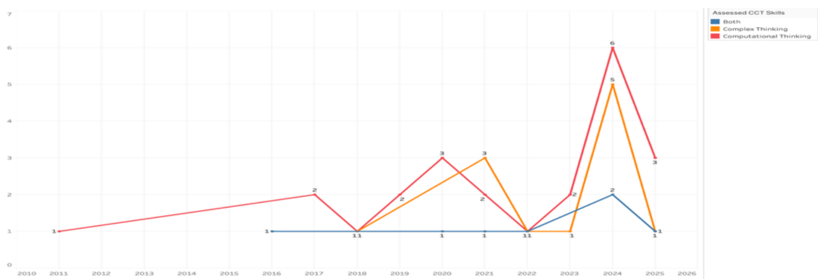

Fig. 4. Research areas of interest

The data reveal a gradual growth in scientific output since 2010, with sharper increases starting in 2019 and a peak in 2023. This increase coincides with the expansion of the use of advanced educational technologies and the growing interest in the development of higher cognitive skills in AI-mediated environments. It highlights that most research has focused exclusively on computational thinking, while complex thinking or integrated assessment of both competencies have received less attention.

RQ4: What is the university academic context and disciplinary area of the study?

To understand the academic context of the studies analyzed, their distribution was analyzed according to university educational level and the scientific discipline involved. This categorization makes it possible to identify the areas of knowledge and educational levels that are leading research. Likewise, the methods used in each case were distinguished to make visible the methodological diversity by disciplinary area (see Figure 5).

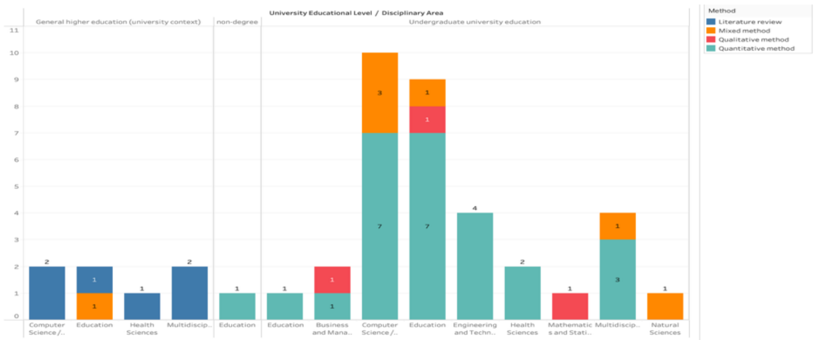

Fig. 5. University academic context and disciplinary area

The results show concentration of studies at the undergraduate level, particularly in the fields of computer science and education, where quantitative approaches predominate. On the other hand, areas traditionally less associated with these competencies, such as natural sciences and applied social sciences are poorly represented, evidencing an opportunity to broaden research towards more interdisciplinary frameworks.

RQ5. What type of educational environment or technological support is used in studies that address the assessment of CCT in HE?

Research was classified according to the type of educational environments and technologies used in studies on the assessment of CCT in HE; in addition, the type of competency assessed was considered, which allowed to establish patterns between the technological support and the evaluative approach adopted by the studies analyzed (see Figure 6).

Fig. 6. Educational environment in the assessment of CCT in HE

The results show a predominance of digital environments and hybrid platforms in studies focused on computational thinking. In contrast, complex thinking tends to be assessed in more varied contexts, including face-to-face classrooms, clinical settings, and online learning platforms. Few studies simultaneously integrate both types of thinking, and when they do, they generally take place in traditional or digitized environments with a collaborative approach.

4 Discussion

Globally, research on the assessment of CCT in HE has been concentrated mainly in a few leading countries. The United States and Taiwan lead the publication with five studies each, followed by Mexico (4) and Spain, China, Thailand, and Indonesia (3) (see Figure 1). The focus on certain territories contrasts with the holistic vision of complex thinking, which emphasizes the diversity of cultural and educational contexts [6]. These results suggest the need to encourage research efforts in underrepresented regions to enrich the global understanding of the assessment of these competencies.

Most of the studies employ empirical approaches, favoring quantitative methods. Figures 2 and 3 illustrate this predominance with 27 empirical articles versus 6 theoretical in Scopus and 9 in WoS. [17, 18] defend quantitative rigor to validate assessment constructs, while [20] warns about the potential of qualitative and mixed approaches to capture the complexity of thinking in educational settings. Consequently, it is recommended that future research integrate mixed designs that combine statistical robustness with the interpretive richness of qualitative data.

Likewise, a sustained growth in scientific production has been observed with an increase from 2019 and a peak in 2023. Figure 4 shows the specialization in computational thinking versus complex or combined thinking, this growth coincides with the expansion of advanced educational technologies and the interest in higher order competencies in AI-mediated environments [2]. However, the relative less attention to complex thinking reflects a dissonance with the postulates of [3], which advocate comprehensive assessments of interrelated skills. Such trends indicate the necessity of developing research frames that balance both dimensions and facilitate deeper longitudinal analyses.

Studies on CCT assessment are mostly concentrated at the undergraduate level and in the disciplines of Computer Science and Education. Figure 5 shows the preponderance of quantitative approaches in these areas, which coincides with STEM initiatives that promote the integration of computational thinking through laboratories and bootcamps [10, 11]. However, [9] stresses the need to extend the assessment of complex thinking to less traditional areas, such as social sciences or humanities. In this way, institutions can design curricular policies that promote contextualized and multidisciplinary assessments, fostering assessment frameworks tailored to each discipline.

Finally, digital platforms and hybrid scenarios dominate computational thinking assessments, while complex thinking is assessed in more diverse settings. Figure 6 depicts the high presence of coding environments, AI-enabled platforms, and mixed models for computational competencies, versus face-to-face or online experiences for complex thinking. These practices are aligned with [10, 12], which highlight the value of computational environments in the development of algorithmic skills. However, the assessment of complex thinking requires scenarios that integrate social interaction and systemic analysis [7, 9].Therefore, it is essential to design educational environments that strategically articulate diverse technologies, favoring holistic CCT assessments in HE.

5 Conclusions

This study analyzed recently published scientific evidence on assessment of CCT in HE, focusing on the research conducted and the analysis of its content. This process allowed us to have an overview of the research in this area regarding the breadth of published studies, the type, approach, and research design followed, geographic distribution of the lead author, and the contexts in which it is studied. From this analysis, we observed that, there is a need for more research directed to the educational aspect, specifically regarding to the assessment of this high-level cognitive abilities.

The study's limitations include that the literature mapping used only two databases, thus restricting the scientific evidence analysis. In conclusion, the article presents a synthetic view of the state of the art on the assessment of CCT with HE and invites scientific inquiry on topics that have been little explored.

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