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Critical thinking, creative thinking, systems thinking and many more: A comparative bibliometric analysis of prevalence and distribution

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ABSTRACT

To compare discourses related to different ways of thinking, a bibliometric analysis was performed on the Dimensions database of research documents. Terms related to 78 ways of thinking were ranked according to the number of documents containing them over the last five years (2020 to 2024). Twenty ways of thinking were subjected to further analyses, examining (i) those that are most prevalent (with the top five being critical thinking, design thinking, creative thinking, systems thinking then computational thinking); (ii) the different suffixes appended to each term (with critical thinking mostly referred to as a skill, systems thinking mostly referred to as an approach and design thinking almost equally referred to as a method, approach and process); (iii) the proportion of documents focusing on each of them, rather than simply referring to them (with computational thinking having the highest such proportion); (iv) their rise to prevalence since 1975 (with critical thinking and systems thinking slowly gaining prevalence compared to the more recent rise of design thinking and computational thinking); (v) the frequency with which they are referred to together (with critical thinking and creative thinking co-occurring most often); (vi) their distribution across various academic disciplines (with futures thinking being quite evenly distributed, but computational thinking being highly concentrated); (vii) their distribution across the Sustainable Development Goals (with critical thinking, systems thinking and design thinking being most prevalent in this respect). The findings and visualisations provide a useful basis for identifying, comparing, selecting and combining different ways of thinking.

1. Introduction

The most recent edition of the World Economic Forum's (2025) report on the *Future of Jobs* ranks "systems thinking," "creative thinking" and "analytical thinking" as some of the most important skills in the workplace (p. 33). It also ranks them as skills that will be of growing importance over the next five years (pp. 35, 41). Similarly, the Royal Academy of Engineering's (2024) report on the skills required by future engineers (*Engineers 2030*) highlights the importance of "systems thinking," "creative thinking" and "critical thinking" (pp. 13–14). To cite another example, the European Commission's report on its *Sustainability Competence Framework* highlights the importance of "systems thinking," "futures thinking," "values thinking," "critical thinking," and "strategic [thinking]" (Scalabrino, 2022, pp. 29–30). In these reports, each way of thinking is valued because it helps people notice, understand and improve various situations. However, the reports also recognise that any single way of thinking is limited, so combining them offers a more complete and flexible approach.

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Although individuals and institutions have sometimes collected ways of thinking into contrasting and complementary sets, it remains unclear how these sets have been formed. Whatever ways of thinking are jointly promoted, there is often little or no explicit justification for those that were included and excluded. Instead, it might seem that the selected ways of thinking are thought to form some obvious or natural grouping. However, across various literatures, many different sets have been formed, even when considering the same specific skill or application area (for a non-exhaustive illustration of this, see Fig. 1). When these sets are proposed, the ways of thinking in each set might be described and celebrated, but other ways of thinking are not necessarily referred to at all. For example, if design thinking, systems thinking and computational thinking are presented as a set, this presentation need not be accompanied by mention of critical thinking, creative thinking or any others. As such, when comparing sets of ways of thinking, it is not clear whether these sets are well composed or if other combinations would provide better focus or coverage.

To meaningfully collect ways of thinking into sets, we must understand how those ways of thinking relate to each other. Although they are most often considered in isolation, there is some prior work comparing them. Such work has explored how they are each defined, the components they are made from and the relationships between those components (e.g. Crilly, 2024; Dalal et al., 2021; English, 2023; Patel & Mehta, 2017; Subramaniam et al., 2024). Contrasting with that conceptual focus, this present article investigates which ways of thinking receive the most attention and where that attention is located. This is done by reporting on a comparative bibliometric analysis of research documents referring to different ways of thinking across periods, disciplines and application areas. This is intended to support researchers in understanding how often each way of thinking is referred to and where those references are found, providing a basis for differentiation, selection and combination.

To establish the broad landscape within which any particular way of thinking sits, this article considers many more than are typically drawn together for analysis. By comparing them, we can address two sets of questions about these ways of thinking:

1. *Prevalence.* How often are they referred to, separately and in combination, and how has this changed over time?
2. *Distribution.* How widely and evenly are they referred to across different disciplines and application areas?

To answer these questions, different bibliometric techniques are reported and applied throughout this article. However, the focus is on the knowledge these methods generate rather than the methods themselves: the contribution is topical, not methodological.

The two sets of research questions are first addressed through a brief narrative review of the published literature (Section 2). The data and analysis methods are subsequently outlined (Section 3) so that the results (Section 4) can be understood. In discussing these results, the general and specific limitations of the study are reviewed to motivate further work that would address them, whether employing bibliometric analyses or other approaches (Section 5). In concluding the article, the contributions of the study are highlighted, emphasising the utility of the findings for different stakeholders (Section 6).

2. Literature review

This journal alone—*and perhaps more than any other*—has presented numerous articles reporting how to conceptualise, develop and assess various ways of thinking. These include studies of critical thinking (Dwyer et al., 2014; Ku, 2009), systems thinking (Grohs et al., 2018; Hrin et al., 2017), creative thinking (Huang et al., 2020; A. Y. Wang, 2012), design thinking (Henriksen et al., 2017; Pande & Bharathi, 2020), computational thinking (Şahin et al., 2024; Sun et al., 2021), entrepreneurial thinking (Sandhu et al., 2025), divergent thinking (Batey et al., 2009; Silvia, 2011) and possibility thinking (Cremin et al., 2006). These ways of thinking have mostly been considered in isolation, but this journal has also presented work exploring the relations between two or more ways of thinking, such as creative thinking and critical thinking (Wechsler et al., 2018), and also creative thinking, critical thinking and reflective thinking (Akpur, 2020).

Although concepts labelled with terms like critical thinking and systems thinking are not often assembled into large sets, they are sometimes referred to as being the same kind of thing. "Ways of thinking" is one label for them (e.g. English, 2023), and it is the one I will adopt throughout this article. Other relevant terms include "thinking skills" (e.g. Butterworth & Thwaites, 2013) "cognitive skills" (e.g. Perkins & Salomon, 1989) "higher order thinking skills" (e.g. Lewis & Smith, 1993) and "21st century skills" (e.g. Thornhill-Miller et al., 2023). To make things more complicated, sometimes a certain way of thinking is considered a component of some other way of thinking. So, analytical thinking might be described as a critical thinking skill, or systems thinking might be described as a creative thinking skill (Crilly, 2024, pp. 52–53). Unfortunately, these terms, hierarchies and groupings are quite inconsistent across authors, disciplines and periods, and do not provide a reliable basis for distinguishing or relating different ways of thinking.

Of course, we might question whether different ways of thinking belong in the same category at all. Should critical thinking be considered the same kind of thing as design thinking? Should either be associated or compared with systems thinking or strategic thinking? Perspectives on these questions would differ, and this confusion partly results from the many possible interpretations of each way of thinking. For example, Kimbell (2011) recognises design thinking as a cognitive style, a general theory and a resource for organizations (p. 285). Kaur and Craven (2022) recognise systems thinking as a set of characteristics, a purposeful achievement and even a system in its own right (p. 193). More generally, and looking across multiple literatures, we might find the word "thinking" appended to certain terms, not to indicate a precise concept (and not necessarily to emphasise *thinking* in particular), but to indicate something that is vague and open to interpretation (Crilly, 2024, pp. 37–39). This raises the prospect of "jingle fallacies," where two or more distinct concepts or phenomena are referred to with the same term (Hanfstingl et al., 2024). For example, conflating a design

Ways of thinking

Publication	Domain	Systems thinking	Design thinking	Critical thinking	Computational thinking	Creative thinking	Strategic thinking	Mathematical thinking	Futures thinking	Values thinking	Entrepreneurial thinking	Scientific thinking	Engineering thinking	Historical thinking	Analytical thinking	Logical thinking	Sustainable thinking	Responsible thinking	Data-scientific thinking	Statistical thinking	General notes
RAEng (2024, pp. 13-14)	Engineering	■	■	■																	1
English (2023, p. 1220)	STEM	■	■	■																	2
Wong et al. (2019, p. 115)	Military	3	■	■																	
Dzombak & Beckman (2020, p.581)	Computer science	■	■	■																	4
Shute et al. (2017, pp. 145-146)	Computer science	■	■		5			■					■								
Crilly (2024, p. 63)	Professional roles	■	■		■						■										6
Singh (2025, p. 80)	General	■	■		■																
Patel & Mehta (2017, p. 525)	Professional roles	■	■								■										7
Scalabrino (2022, pp. 29-30)	Sustainability	■		■			8		■	■											
Teqja (2016, pp. 549-552)	Education	9		■		■															
Waters (2011, p. 115)	Military	■		■		■			10					11							
World Economic Forum (2025, p. 41)	Professional roles	■				■									■						12
Kalluri et al. (2024, pp. 946)	Computer science	■				■	■									■	■	■			13
Rieckmann (2018, 44)	Sustainability	■		■			■		14	15											
Dalal (2021, pp. 112-113)	Engineering	■					16		■	■											
Subramaniam et al. (2024, p. 4)	Engineering design		■		■			■				■									17
Apiola & Sutinen (2021, p. 85)	Computer science				18			■				■	■								
Gould (2021, pp. S13-S19)	Data science				■			■											19	■	

Notes:

1. Also refers to "analytical thinking."

2. These contribute to "adaptive and innovative thinking."

3. Also refers to "soft systems methodology."

4. These contribute to "problem framing and solving."

5. Computational thinking requires/includes the others.

6. Also details many other ways of thinking.

7. Argues that these ways of thinking are integrated in practice.

8. Refers to "strategic action-oriented … competence."

9. "Systems" and "systemic" are used synonymously.

10. Refers to "futuring."

11. Refers to "thinking in time."

12. Also refers to "design and user experience."

13. These contribute to "critical thinking" in computer science.

14. Refers to "anticipatory competency."

15. Refers to "normative competency."

16. This is related to "critical thinking."

17. Also includes "metacognitive reflection" at the same level.

18. Computational thinking requires/includes the others.

19. Data-scientific thinking requires/includes the others.

Fig. 1. Examples of documents promoting ways of thinking in sets (limited here to sets of three or more). The ways of thinking are ordered by prevalence (in this set); the documents are ordered by inclusion of the most prevalent ways of thinking.[11]

thinking process with a design thinking mindset would fail to acknowledge distinctions between design thinking as a set of procedures and design thinking as personal outlook or inclination.

The multiple meanings attached to each way of thinking makes it difficult to define the more general category they all belong to. However, in broad terms, they are understood as influencing how a person sees the world, orients toward it and acts upon it, typically through a collection of cognitive styles, habits of mind, attitudes, logics, values or perspectives (Crilly, 2024, p. 40). Consistent with this broad concept, many ways of thinking have been described as characteristic of certain academic disciplines, professional practices or regional cultures (Entwistle, 2019, pp. 1, 16; Nakamura, 1991, p. 5). Notably, these specific ways of thinking have received the most attention, rather than any higher-level category to which they belong. Whatever level we are examining, some scepticism should be maintained over whether the neatly named categories (e.g. "ways of thinking" or "critical thinking") align with meaningful psychological concepts (Brick et al., 2022). Here, it is the category names that are studied, because their prevalence and distribution are important for research and practice, but this should not be taken to imply that these category names are aligned with distinct cognitive processes.

This article includes many ways of thinking so that researchers can locate those important to them and perhaps identify some they had previously overlooked. Put simply, a way of thinking is included here if it takes the form "*[variant]* thinking," unless the variant modifier represents a value judgement on thinking rather than a way of thinking. So, "futures thinking" is included, but "futile thinking" is not. In addition to observing that not everything labelled in the format "*[variant]* thinking" should be included in this analysis, we might also question whether there are other ways to refer to what should be included. For example, consider "entrepreneurial mindset," scientific attitude" or "thinking like a lawyer." These alternative terms point to relevant concepts, even if those concepts are more often referred to with terms taking the form "*[variant]* thinking" (Crilly, 2024: Appendix A). This raises the prospect of "jangle fallacies," where different terms are used to describe the same concepts or phenomenon (Hanfstingl et al., 2024). Conflating the scientific method with a scientific attitude would be one kind of error (related to a jingle fallacy), but spuriously distinguishing between scientific thinking and a scientific attitude would be another (a jangle fallacy). For practical reasons, alternative terms are excluded here because the number of ways of thinking is already very large, even without including other naming formats (see Sections 3.1 and 5.3 for further discussion of the included terms). In addition, this scope restriction is consistent with the description of many ways of thinking sets, where the act of collection and comparison seemingly encourages some consistency in the naming format.

Having established the context for working with certain terms, let us focus on the questions of prevalence and distribution.

2.1. Prevalence

Many studies of ways of thinking make claims about how commonly they are referred to, how often they are implemented and how quickly this is increasing. For example, systems thinking, is claimed to be generally important (Arnold & Wade, 2015, p. 670) and of growing influence across disciplines (Mambrey et al., 2020, p. 1645). Similar claims can be found for many other ways of thinking, including critical thinking (Halpern & Sternberg, 2020, p. 4), design thinking (Razzouk & Shute, 2012) and computational thinking (Wing, 2008, p. 3720). It is rare for these claims about prevalence to be made comparatively, but one example is Kelly and Gero's (2021) observation that "design thinking and computational thinking are the only two forms of thinking to gain prominence since the turn of the 21st century" (p. 2).

Considering prevalence raises questions about whether any ways of thinking are associated with other topics, practices or technologies that are gaining momentum. On this point, attention has turned to the influence that use of artificial intelligence (AI) has on various ways of thinking, with some claiming that it improves them (Ilgun Dibek et al., 2024) and others that it compromises them (Lindebaum & Fleming, 2024). Specific ways of thinking examined in this respect include critical thinking (Larson et al., 2024), systems thinking (Arndt, 2023; Qudrat-Ullah, 2025), design thinking (Sreenivasan & Suresh, 2024), creative thinking (Fan & Zhong, 2022), computational thinking (Dohn et al., 2022), possibility thinking (Beghetto, 2023) and certain combinations of these (Albakry et al., 2025). There are also discussions of "AI thinking," which describes not how AI systems think, but how human users should think when effectively interacting with AI (Newman-Griffis, 2025; also see Zeng, 2013). This increased attention to how people and computers work together might suggest a growing role for research on ways of thinking, but this has seemingly not been measured or reported.

Claims about prevalence are seemingly only quantified in focused bibliometric studies. These have independently analysed the literature on several ways of thinking, including critical thinking (Pagán Castaño et al., 2023), systems thinking (Hossain et al., 2020), creative thinking (Park & Lee, 2022), design thinking (Leal Filho et al., 2024), computational thinking (Chen et al., 2023), reflective thinking (Korkmaz & Toraman, 2024) and mathematical thinking (Evendi, 2022). Such studies generally report an increasing frequency of relevant publications over time and list the most cited or influential works. However, a collection of isolated analyses prevents a reliable assessment of the relative prevalence of these concepts (compared to each other) or how that relative prevalence has changed over time. This is because the studies draw from different datasets, apply different search strategies and analyse the data in different ways. These methodological variations obscure any real differences in the prevalence of each way of thinking. Such fragmentation can be contrasted with bibliometric analyses of other concepts, where explicit comparisons have been made from the same datasets using the same methods (e.g. Ponomarenko et al., 2024; Vysochan et al., 2022).

One rare example of a comparative bibliometric study focused on ways of thinking is Crilly's (2024) report on a simple count of the number of research publications that refer to various ways of thinking. However, the focus is on ways of thinking that are strongly associated with specific professional practices (such as engineering thinking and entrepreneurial thinking), rather than those that are more general (such as critical thinking or creative thinking). Still, within the set considered, systems thinking is reported as the most prevalent term in the literature, followed by design thinking, computational thinking, scientific thinking and mathematical thinking (p. 10; also see Appendices A and B). So, this analysis could offer a starting point for comparison, but again, only some ways of thinking were considered, and there is no report on how attention to these has changed over time or how that attention is distributed across academic disciplines or application areas.

2.2. Distribution

The various ways of thinking considered here originate from different communities that have not coordinated with each other when developing their concepts. This was illustrated in Crilly's (2024, p. 44) analysis of how often certain terms appear together, specifically design thinking, systems thinking, entrepreneurial thinking and computational thinking. Based on a title, abstract and keyword search focused on seventy years of publications, the total count of documents referring to any of these four terms was over 21,252, whereas only 285 (around 1.34 %) referred to any combination of them. A related co-citation analysis of the literatures discussing those same four concepts showed that they are effectively independent of each other (Appendix B). This contrasts with the overlaps identified between ways of thinking, such as the problem-solving focus shared by design thinking, systems thinking and entrepreneurial thinking, and the modelling and simulation focus shared by computational thinking and systems thinking (Crilly, 2024, p. 63).

Despite the discipline-bound discussion of some ways of thinking, they are nevertheless described as invaluable skills for everyone to develop, irrespective of discipline or practice. For example, Pressman (2018) tells us that design thinking is "[n]ot just for architects or product developers, [but] can be applied across many disciplines" (p. xvii). Similarly, Wing (2006) claims that computational thinking "is a fundamental skill for everyone, not just for computer scientists" (p. 33). So, it seems that everyone should think like a designer or computer scientist, but to what extent have other disciplines picked up on the idea of design thinking and computational thinking? More generally, we might ask whether ways of thinking are distinguished from each other by the extent to which different communities have recognised, discussed and applied them.

There is evidence that some ways of thinking are relevant across disciplines, such as example applications of design thinking in business (Carr et al., 2010) and policy making (Mintrom & Luetjens, 2016), systems thinking in healthcare (Peters, 2014) and safety (Leveson, 2016), and critical thinking in finance (Hallows & White, 2016) and warfare (Antrobus & West, 2022). There have also been suggestions that some ways of thinking might be exhibited differently across disciplines. For example, Barr & Stephenson (2011) suggest how various aspects of computational thinking apply to various school subjects, including maths, science, social studies and languages.

Despite the numerous claims made for the relevance of various ways of thinking across disciplines, there has seemingly been no attempt to make systematic measurements or comparisons. This contrasts with other studies of interdisciplinarity, where efforts to quantify cross-domain application and relevance have a long history (A. L. Porter & Chubin, 1985; J. Wang et al., 2015). However, especially when considering comparative empirical approaches, such systematic enquiry into ways of thinking would be very demanding. It would seemingly require many ways of thinking to be assessed against many disciplines or domains, resulting in a study design with a large matrix of conditions within which to observe and measure behaviour. Bibliometric approaches promise to be more tractable, even if used to generate proposals that should be tested and elaborated with other methods.

In this study, bibliometric data are analysed to answer two sets of questions about the discourse surrounding various ways of thinking in the research literature:

1. *Prevalence*
   a. How often is each way of thinking referred to?
   b. How often are different interpretations of each way of thinking referred to?
   c. How often is each way of thinking referred to in prominent document locations?
   d. How has the prevalence of each way of thinking changed over time?
   e. How often are ways of thinking referred to together (in pairs)?
2. *Distribution*
   a. How widely and evenly is each way of thinking referred to across disciplines?
   b. How widely and evenly is each way of thinking referred to across application areas?

In addressing these questions, the study aims to contribute to our understanding of how different ways of thinking are referred to, in what ways and in what contexts. In conjunction with prior conceptual analyses, this is intended to support researchers in identifying, differentiating, selecting and combining different ways of thinking.

3. Methods

Compared to systematic reviews and meta-analyses, bibliometric analyses are suited to situations where the scope of the review is broad and the dataset is too large to review manually (Donthu et al., 2021, p. 287). There is well-established guidance for reporting systematic and meta-analytic reviews, such as the PRISMA checklist (Page et al., 2021). However, similar guidance for bibliometric analyses has only recently been introduced in the form of the preliminary Guidance List for the repOrting of Bibliometric AnaLyses: GLOBAL (Ng et al., 2024, pp. 41–43). This article adheres to all recommendations in that 32-item list.

The data for all analyses reported here were drawn from the 'Dimensions Analytics' database from Digital Science (Digital Science, 2025; Wastl, 2020). The database contains over 150 million research documents, including (with approximate proportions indicated) articles (80 %), chapters (10 %); proceedings (6 %); preprints (3 %), monographs (<1 %), edited books (<1 %) and seminars (<1 %). The "articles" category includes works "from a scientific journal or trade magazine, including news and editorial content" (Digital Science, 2019).

The Dimensions database has been shown to be comparable to other bibliographic databases for purposes of bibliometric analyses (Thelwall, 2018), but is larger and more cross-disciplinary than many of them (Basson et al., 2022; Guerrero-Bote et al., 2021). In a recent comparison of 56 bibliographic databases, Dimensions was ranked 9th for the number of documents included (ahead of Scopus and Web of Science, but behind Semantic Scholar and Crossref), and 15th for multidisciplinary breadth (ahead of Science Citation Index and ScienceDirect, but behind Scopus and Web of Science) (Gusenbauer, 2022, pp. 2711, 2718).

Critically, the study reported here draws on two document-level categories that are unique to Dimensions: one for disciplines and one for application areas (see Sections 3.5 and 3.6). In addition, the study uses Dimensions "concept" keywords, which are identified consistently from documents, regardless of whether authors or publications allocated them to documents (see Section 3.4).

Between February and June 2025, the database web interface was repeatedly searched for documents including different terms (see Sections 3.1) in different document locations and date windows (see Sections 3.2); no other filters were applied. The units of analysis were individual documents, which are here considered micro-level outputs of research. The main bibliometric method used was performance analysis based on the count of total documents returned by each search query (for alternative approaches, see Donthu et al., 2021, pp. 287–288). All publication types and document types were included (Digital Science, 2019), and only document quantity indicators were used, not quality or structure indicators.

The full dataset is typically analysed in a study of this kind (Rogers et al., 2020, p. 777), but the data might not be entirely clean or reliable (De Battisti & Salini, 2013, p. 272). To address this, the quality of the data was evaluated (Donner, 2024, p. 1). No data filtering or cleaning was performed, but a random sample of results was assessed for quality (see Section 3.3). Data storage, manipulation and visualisation were performed using Microsoft Excel for Mac (Version 16.97), and the data are available for inspection and reuse (see the Data availability statement). In addition to standardisation and normalisation of the data, calculations were performed to determine the Pearson correlation coefficient and Gini coefficient (see Section 3.6).

3.1. Search terms

To identify a suitably large number of ways of thinking to examine, the lists offered in previous narrative reviews were collated. The starting point was two lists compiled by Crilly (2024), one focused on discipline-specific ways of thinking (pp. 2–3) and one focused on discipline-neutral ways of thinking (pp. 50–51). Further additions were made through narrative review. The resulting combined list consists of 78 items (see Table 1), but is not claimed to be exhaustive. Some terms include plurals in parentheses and any hyphens are omitted. This is because the Dimensions database does not distinguish between search terms that are singular, plural or hyphenated (Digital Science, 2024). For example, searching for "system thinking," "systems thinking" or "systems-thinking" returns identical results. The 20 ways of thinking with the highest prevalence were identified, and these remained the focus for analysis.

Table 1
List of all search terms included in the initial analysis, sorted alphabetically.

algorithmic thinking	divergent thinking	networked thinking
analogic thinking	economic thinking	non-linear thinking
analogical thinking	engineering thinking	open thinking
analytic thinking	entrepreneurial thinking	open-minded thinking
analytical thinking	evolutionary thinking	physics thinking
anthropological thinking	flexible thinking	policy thinking
architectural thinking	future(s) thinking	possibilistic thinking
artistic thinking	geographic thinking	possibility thinking
causal thinking	geographical thinking	reflective thinking
chemical thinking	hierarchical thinking	responsible thinking
collaborative thinking	historical thinking	scenario thinking
communicative thinking	holistic thinking	scientific thinking
complex thinking	innovation thinking	social thinking
complexity thinking	innovative thinking	sociological thinking
computational thinking	interdisciplinary thinking	statistical thinking
conceptual thinking	intuitive thinking	strategic thinking
contextual thinking	inventive thinking	strategy thinking
convergent thinking	lateral thinking	sustainability thinking
craft thinking	legal thinking	sustainable thinking
creative thinking	linear thinking	systematic thinking
creativity thinking	literary thinking	systemic thinking
critical thinking	logical thinking	system(s) thinking
cultural thinking	mathematical thinking	technological thinking
data-scientific thinking	medical thinking	transdisciplinary thinking
design thinking	model-based thinking	values thinking
designerly thinking	network thinking	visual thinking

3.2. Search fields

To identify works in which a particular way of thinking is referred to in *prominent* document locations, a title-abstract search was performed. To examine documents that simply refer to a particular way of thinking *anywhere* in the text, the full text of the document was searched instead (this includes the reference list).

To examine the prevalence of each way of thinking and to identify trends in the data, two time windows were examined. To capture the present situation, the last five full years (at the point of data collection) were examined: from the beginning of January 2020 to the end of December 2024. This provided a searchable corpus of 36,497,687 documents, which converts to a mean count of 7,299,537 documents per year over that five-year period.

Examining data from much longer time windows would skew the analysis toward those ways of thinking that have a long history. To examine longer trends in the data, the last 50 full years were examined: from the beginning of January 1975 to the end of December 2024. This provided a searchable corpus of 135,300,836 documents, which converts to a mean count of 2,706,017 documents per year over that fifty-year period. The total volume of published work (across all topics) trends upwards over time (see Fig. 2). This general trend in publication volume can obscure any specific trends related to the search being performed. Consequently, when reporting changing prevalence over time, preference is given to reporting the proportion of all documents published each year that satisfied the search criteria (e.g. the percentage of all documents that refer to “critical thinking”).

3.3. Data evaluation

In this study, millions of documents were returned from hundreds of individual search queries. Manually evaluating each returned document for relevance and inclusion was not feasible. Instead, a manual review was performed on a random sample of the 100 documents returned when searching for each of the five most prevalent terms: critical thinking, design thinking, creative thinking, systems thinking and computational thinking (title-abstract search restricted to the last five full years; see Section 4.1). The title and abstract for each of these 500 documents were inspected to assess how the terms were used in context. The objective was to identify any erroneous search results (e.g. where the terms were not present) or documents where the word pairs were used in a way that did not refer to some way of thinking (e.g. where the word pairs only appear in some unrelated grammatical construction). English language translations were obtained where the term was embedded in another language.

The manual review of the sample confirmed that search queries were returning relevant documents. There were no instances where search terms were identified as part of a grammatical construction that referred to something other than a way of thinking. However, the title-abstract search in the Dimensions database additionally identifies keywords where these are available in the full text (Digital Science, 2024). These keywords are not provided in the downloadable search results, and not all documents could be accessed for manual inspection. Overall, 97.00 % of the 500 documents were verified as conforming to expectations, with 1.20 % remaining uninspected and 1.80 % identified as anomalous. These anomalous documents fell into three categories: (i) the relevant terms did not appear in the title, abstract or keywords; (ii) the abstract included a reference list including the relevant term; (iii) the published document had been retracted. Across the many documents reported in the full analysis, we can expect some truly erroneous results are

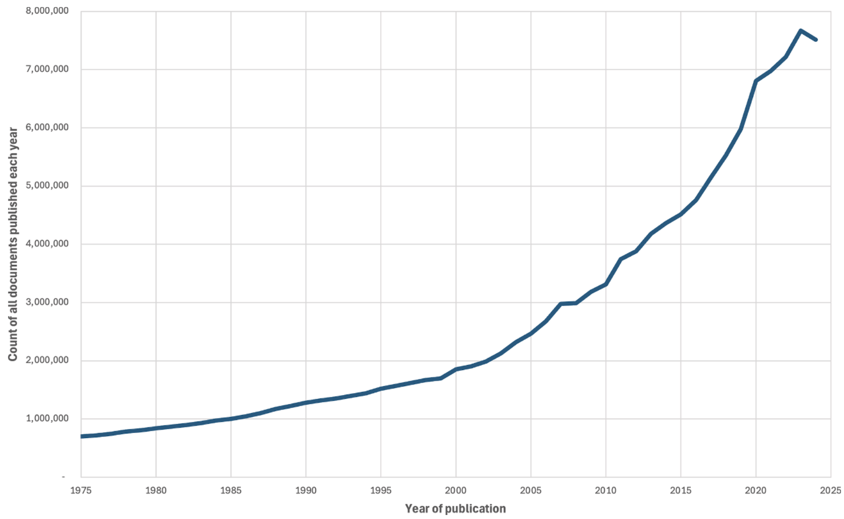

Fig. 2. Line chart illustrating the varying count of documents published each year over five decades. Dimensions database: date range from 1 January 1975 to 31 December 2024.

Table 2
The 34 Units of Assessment (UoAs) defined by UK Research and Innovation (UKRI), along with their mean annual document count over a five-year period. Dimensions database; date range from 1 January 2020 to 31 December 2024.

Panel	Unit of Assessment	Documents/ year
A: Medicine, Health and Life Sciences	A01: Clinical Medicine	597,381
	A02: Public Health, Health Services and Primary Care	90,065
	A03: Allied Health Professions, Dentistry, Nursing and Pharmacy	638,146
	A04: Psychology, Psychiatry and Neuroscience	195,745
	A05: Biological Sciences	122,615
	A06: Agriculture, Food and Veterinary Sciences	199,678
B: Physical Sciences, Engineering and Mathematics	B07: Earth Systems and Environmental Sciences	122,984
	B08: Chemistry	129,481
	B09: Physics	133,699
	B10: Mathematical Sciences	156,014
	B11: Computer Science and Informatics	464,397
	B12: Engineering	1,231,045
C: Social Sciences	C13: Architecture, Built Environment and Planning	79,204
	C14: Geography and Environmental Studies	81,448
	C15: Archaeology	11,915
	C16: Economics and Econometrics	16,317
	C17: Business and Management Studies	379,443
	C18: Law	80,636
	C19: Politics and International Studies	51,625
	C20: Social Work and Social Policy	50,203
	C21: Sociology	14,854
	C22: Anthropology and Development Studies	18,673
	C23: Education	213,558
	C24: Sport and Exercise Sciences, Leisure and Tourism	61,412
D – Arts and Humanities	D25: Area Studies	10,809
	D26: Modern Languages and Linguistics	47,388
	D27: English Language and Literature	42,129
	D28: History	54,366
	D29: Classics	5,019
	D30: Philosophy	17,542
	D31: Theology and Religious Studies	14,829
	D32: Art and Design: History, Practice and Theory	35,625
	D33: Music, Drama, Dance, Performing Arts, Film and Screen Studies	19,982
	D34: Communication, Cultural and Media Studies, Library and Information Management	34,293
	Total:	**5,422,518**

included, but these would seem to represent only a small fraction (see further discussion in Section 5.3).

3.4. Common suffixes

To investigate variation in the meanings attached to each search term, it is useful to identify the suffixes that are appended to them, such as "critical thinking *skill,*" "critical thinking *approach*" and critical thinking *process*." This is important because two documents using a single term might do so with different meanings.

For any search query, the Dimensions database returns a list of AI-generated *concepts*: "noun-phrases automatically extracted from a document's abstract as well as the rest of the Dimensions database" (Digital Science, 2020a). These concepts are well-suited to bibliometric analyses because they have the descriptive power of author keywords without the influence of author biases (Gupta & Singh, 2024, p. 1050).

A query was run for each search term to identify the most relevant Dimensions concepts. Reviewing these concepts yielded the most common suffixes appended to the search terms. This permitted analysis of the prevalence and distribution of these suffixes within and across each search term.

3.5. Discipline categories

To examine how each way of thinking is distributed across disciplines requires the documents mentioning them to be associated with particular disciplines. The Dimensions database classifies individual documents according to the 34 Units of Assessment (UoAs) defined by the UK's Research Excellence Framework (Digital Science, 2020b; UKRI, 2021). Compared to the alternative Fields of Research (FoR) classification (see S. J. Porter et al., 2023), the UoA classification is based on article contents rather than journal categories. In this study, this document-level classification method has the advantage of being consistent with the method used for classifying the application areas (see Section 3.6). In both cases, the method of classification involved the Dimensions team producing, checking and curating extensive search queries derived from the official descriptions of the categories. Natural language processing and machine learning techniques were used to build the classification schemes that allocate individual documents to each category (for a detailed description of the process, see Wastl et al., 2020, pp. 4–5). Over the most recent five-year period, the mean annual document counts relevant to each UoA range from approximately 5,000 to 1,200,000 (see Table 2).

Table 3
The 17 Sustainable Development Goals (SDGs) defined by the United Nations, along with their mean annual document count over a five-year period. Dimensions database: date range from 1 January 2020 to 31 December 2024.

Number and short title	Full title	Documents/ year
SDG 1: No Poverty	End poverty in all its forms everywhere	5,694
SDG 2: Zero Hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture	62,508
SDG 3: Good Health and Well Being	Ensure healthy lives and promote well-being for all at all ages	592,880
SDG 4: Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	166,789
SDG 5: Gender Equality	Achieve gender equality and empower all women and girls	22,658
SDG 6: Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all	14,192
SDG 7: Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy for all	257,509
SDG 8: Decent Work and Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	31,362
SDG 9: Industry, Innovation and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	29,108
SDG 10: Reduced Inequalities	Reduce inequality within and among countries	20,802
SDG 11: Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient and sustainable	45,479
SDG 12: Responsible Consumption and Production	Ensure sustainable consumption and production patterns	32,019
SDG 13: Climate Action	Take urgent action to combat climate change and its impacts	96,428
SDG 14: Life Below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	34,463
SDG 15: Life on Land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	62,529
SDG 16: Peace, Justice and Strong Institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	107,343
SDG 17: Partnerships for the Goals	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	1,493
	Total:	**1,583,255**

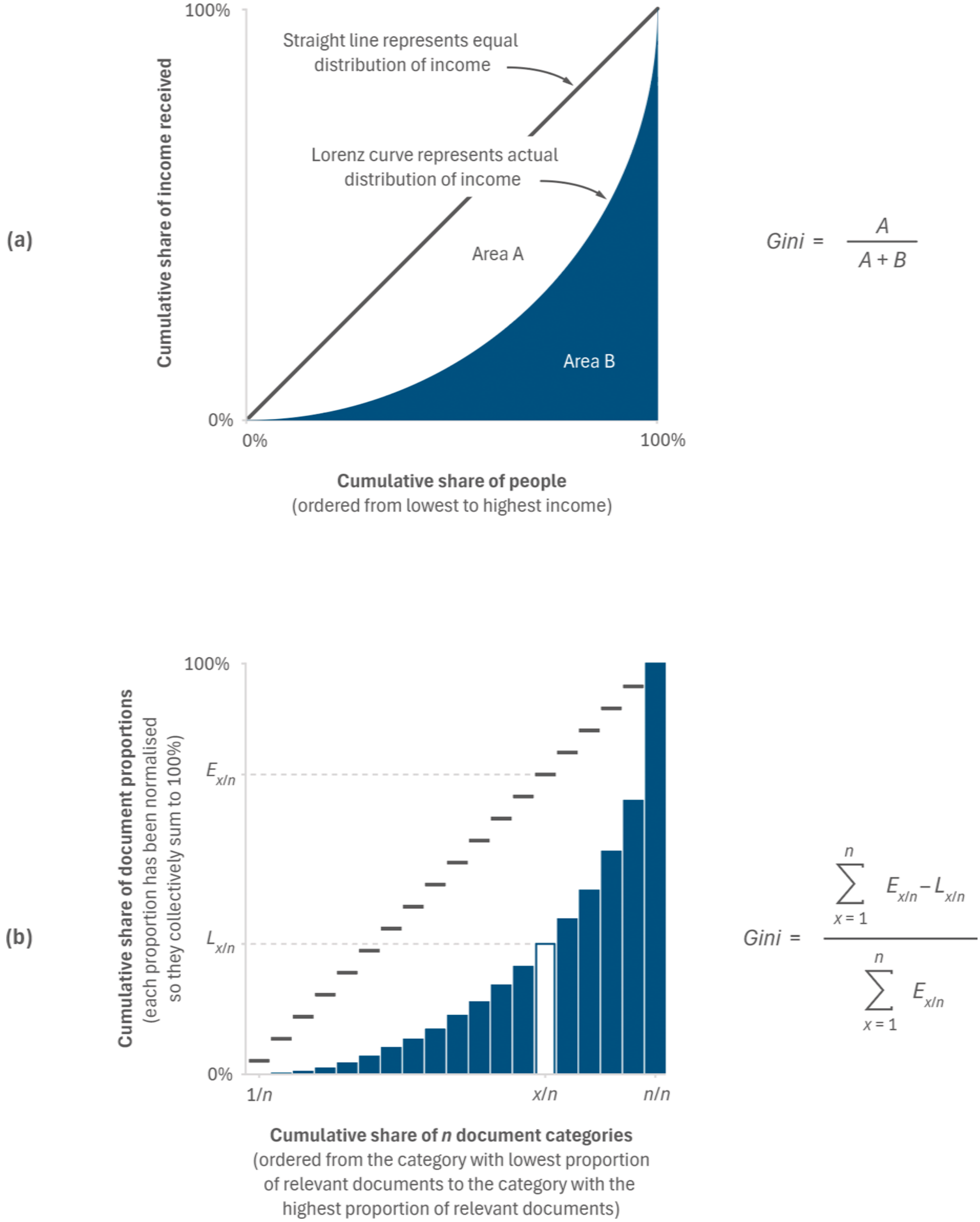

Fig. 3. (a) The standard definition of the Gini coefficient, representing the unequal distribution of income across people. (b) The implementation of the Gini coefficient in this study, representing the unequal distribution of concepts across categories (e.g. disciplines or application areas). This is based on the proportions (rather than counts) of all documents in each category that contain the relevant term.

3.6. Application categories

To examine how each way of thinking is distributed across application areas requires documents mentioning them to be associated with some kind of problem or project. The Dimensions database classifies documents according to the 17 Sustainable Development Goals (SDGs) defined by the United Nations (2015). This provides a view of research addressing major social, environmental and economic questions, a view that is independent of disciplines (Jackson, 2020; Wastl et al., 2020). Over the most recent five-year period, the mean annual document counts relevant to each SDG range from approximately 1,500 to 590,000 (see Table 3).

3.7. Equality of distribution

Ways of thinking for which discussion is quite evenly spread across many or all disciplines might be considered relatively discipline-neutral. In contrast, ways of thinking for which discussion is concentrated in only one or a few disciplines might be considered relatively discipline-specific. The same logic can be applied to areas of application.

Some disciplines (here defined by the UoAs) have higher publication rates than others (see Table 2). As such, simply counting the number of documents referring to each way of thinking (per year) in each discipline would skew the results towards larger or more productive disciplines (e.g. B12: Engineering). Comparing the proportions of documents in each discipline that refer to a way of thinking is more revealing. When describing the distribution of ways of thinking across disciplines, it is the distribution of these proportions that is reported. The same logic is applied to areas of application (here defined by the SDGs).

To obtain a quantitative measure of the equality of distribution of ways of thinking across disciplines, an accepted measure of interdisciplinarity is applied, based on the Gini coefficient (Chu & Evans, 2021; Q. Wang & Schneider, 2020). This is a measure of the inequality among the values of a frequency distribution, most typically levels of population income. As implemented here—*and considering the theoretical extremes*—for a particular way of thinking, a Gini coefficient of zero would indicate that the publications of all disciplines have the same proportion of documents referring to that way of thinking; a Gini coefficient of one would indicate that only a single discipline refers to that way of thinking. Interdisciplinarity is negatively correlated with the Gini coefficient, and so "1-*Gini*" is used as the measure of interdisciplinarity (Q. Wang & Schneider, 2020, p. 243). Here, that measure can be described as a quantification of the *evenness* with which reference to a specific way of thinking is distributed across disciplines (see Fig. 3). The same logic is applied to areas of application.

4. Results

The analyses are structured here according to the seven research questions posed at the end of Section 2.2. Five of those questions

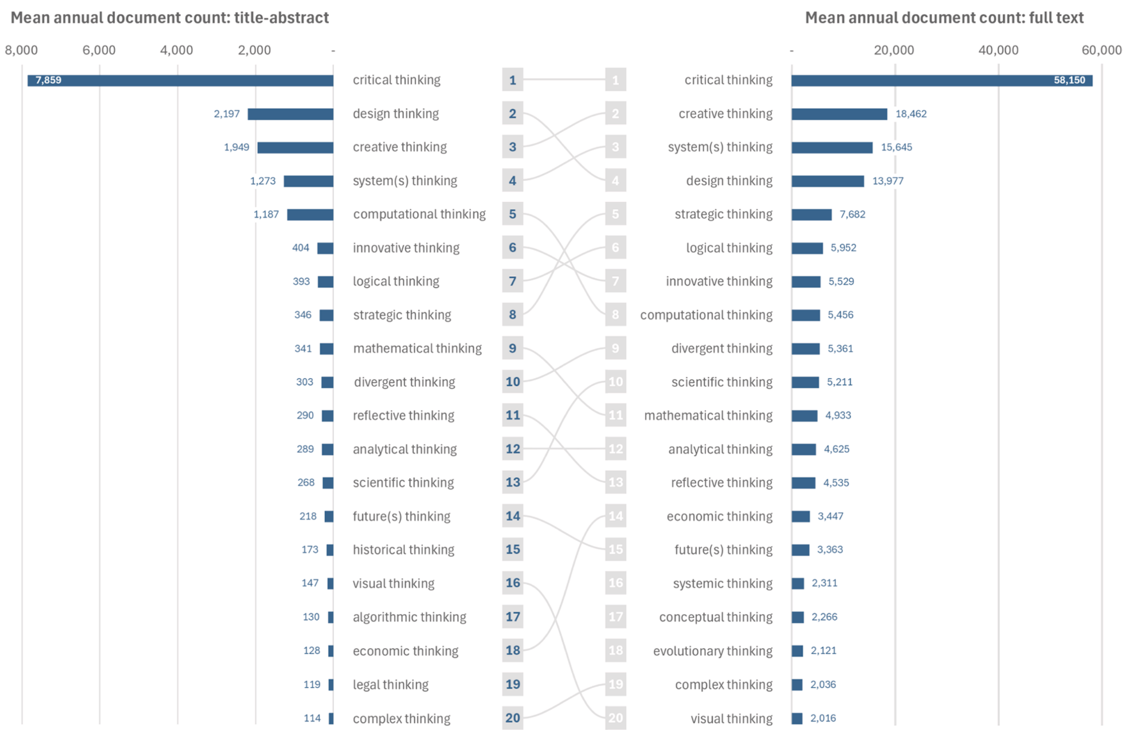

Fig. 4. Paired bar graphs showing the prevalence of the top 20 ways of thinking in the research literature over the last five full years. Dimensions database: title-abstract search (left); full text search (right); date range from 1 January 2020 to 31 December 2024.

focus on the prevalence of search terms (addressed in Sections 4.1 to 4.5) and two focus on the distribution of those terms (addressed in Sections 4.6 and 4.7).

4.1. Prevalence in the corpus

To assess engagement with different ways of thinking, the Dimensions database was searched for documents containing each of the 78 terms listed in Table 1. Restricting the search to the title and abstract fields focused the analysis on terms that occupy a prominent location in each document. Restricting the search to the last five full calendar years (2020–2024) focused the analysis on current rather than historical use. The top 20 terms resulting from this search are listed in Fig. 4 (left plot). Critical thinking is the most prevalent, with a mean annual document count (7,859/year) that is approximately four times higher than the second and third terms: design thinking (2,197) and creative thinking (1,949).

To assess the prevalence of each way of thinking more broadly, including use of the terms in less prominent document sections, the database was searched for the same 78 terms, but now reviewing the full text. The top 20 terms resulting from this search are listed in Fig. 4 (right plot). Again, critical thinking is the most prevalent term (now with 58,150 documents/year, approximately seven times more than were found through the title-abstract search). On the basis of this full-text search, critical thinking is approximately three to four times more prevalent than each of the next two terms: creative thinking (18,462) and systems thinking (15,645). The rank order of terms now differs from that obtained from the title and abstract search. Most notably, design thinking falls from second to fourth place. However, looking across the full-text top ten, only mathematical thinking drops out (to 11th position), replaced by scientific thinking (from 13th position).

Throughout the remaining analyses, both title-abstract and full-text searches are used, depending on the focus of the analysis. However, only 20 ways of thinking are examined from now on, namely those listed in the left plot of Fig. 4, defined by their prevalence in title-abstract searches over a recent five-year period. The convenient phrase “top 20” is not intended to imply any claims about importance or acceptance, just prevalence in this specific search.

Within the top 20 terms identified from the title and abstract search described above, two terms have close relations that can be found in Table 1. Systems thinking (1,273 documents/year) might conceptually overlap with both systemic thinking and systematic thinking (110 and 83, respectively). Similarly, innovative thinking (404 documents/year) might overlap with innovation thinking (13). For systems thinking and innovative thinking, the dominant term is used much more than the other variants. Combining these terms would not, for example, change any position of these terms in the rankings illustrated above. Only the dominant terms are examined further, but issues of related and overlapping terms, including those taking on other forms, are further discussed in Section 5.3.

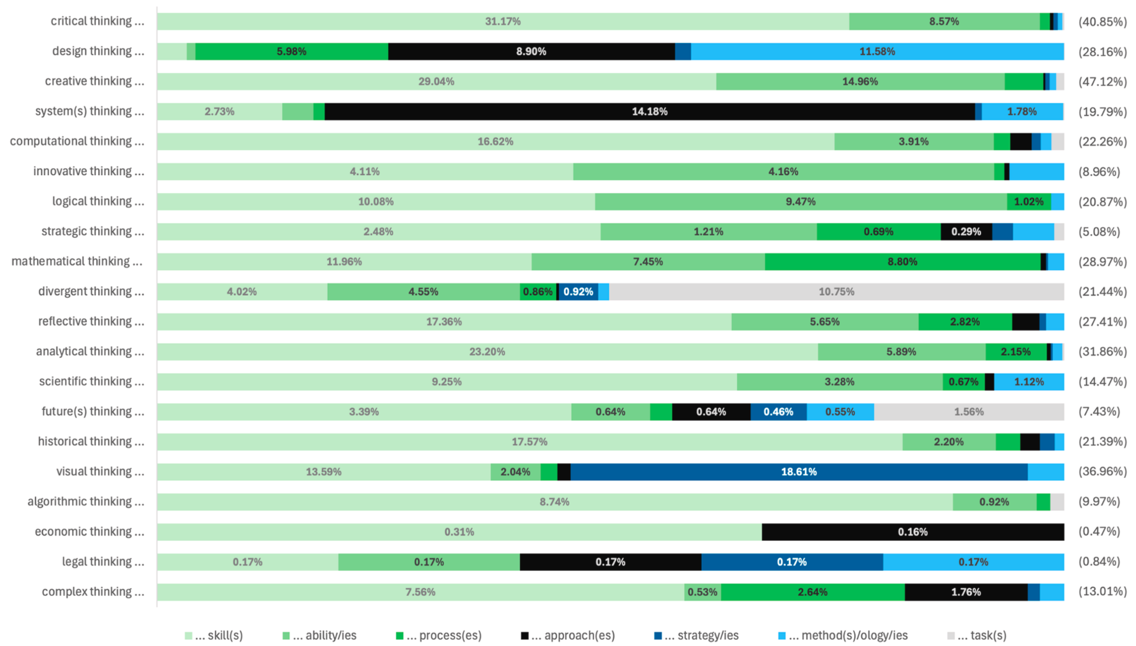

Fig. 5. Stacked bar graph showing the proportions of documents referring to each of 20 ways of thinking in conjunction with seven suffixes. Numerical values are provided for those bars large enough to contain them. The sum of all seven proportions is provided in brackets to the right of each bar stack, indicating the scale for that stack, which is different for each way of thinking. Dimensions database: title-abstract search; date range from 1 January 2020 to 31 December 2024.

4.2. Variations in meaning

For each of the top 20 ways of thinking, the 20 most relevant Dimensions concepts were identified (see Section 3.4). From these 400 concepts, all suffix phrases were retained, such as "critical thinking *skill*," "design thinking *method*" and "creative thinking *ability*." In total, seven suffixes were found to be commonly appended to the ways-of-thinking terms (combining plurals and other variants), listed here in order of decreasing frequency across the 20 ways of thinking: (1) skill(s), (2) ability/abilities (3) process(es), (4) approach(es), (5) strategy/strategies, (6) method(s)/methodology/methodologies, (7) task(s).

For simplicity, the singular form of each suffix is referred to below, but all reported values include the sum of singular, plural and variant forms.

For each way of thinking, a series of five-year title-abstract queries was run, including each of the seven suffixes. The document count returned for each search was converted to a proportion of the document count for that way of thinking (independently of any suffix). For some ways of thinking, one or more of the seven suffixes appeared in a high proportion of documents (see Fig. 5). For example, around 40 % of documents referring to creative thinking or critical thinking append "skill" or "ability" to those terms. In contrast, economic thinking and legal thinking had no suffixes suggested in the concepts list, and very low document counts were returned when searching for the seven suffixes listed here (summing to less than 1 % in each case).

For most of the ways of thinking analysed (14 of the 20), "skill" was the most prevalent suffix, appearing in a high proportion of documents referring to critical thinking (31.17 %), creative thinking (29.04 %), analytical thinking (23.20 %), reflective thinking (17.36 %) and computational thinking (16.62 %). Notable exceptions to this pattern were ways of thinking where something other than "skill" was the most prevalent suffix: systems thinking ("approach," 14.18 %) and divergent thinking ("task," 10.75 %). In addition, two ways of thinking were identified as having multiple common suffixes: design thinking ("method," 11.58 %; "approach," 8.90 %; "process," 5.98 %) and mathematical thinking ("skill," 11.96 %; "process," 8.80 %; "ability," 7.45 %").

4.3. Prominence in documents

Within each document, the relevant search term can be found in prominent locations, such as the title and abstract, or might only be found in other less prominent locations. Occupying a prominent location might indicate that the term is quite central to the document's focus, whereas occupying less prominent locations might indicate that the term is used more incidentally. To assess this prominence, the number of documents containing each term in the title and abstract was divided by the number of documents containing each term in the full text. This proportional measure accounts for the different volumes of literature associated with each way of thinking, meaning that prevalence and prominence can be treated independently (see Fig. 6).

Some terms were found to occupy prominent locations more often than other terms. For example, 21.75 % of documents referring to computational thinking do so in the title, abstract or keywords, and comparable proportions were found for design thinking and

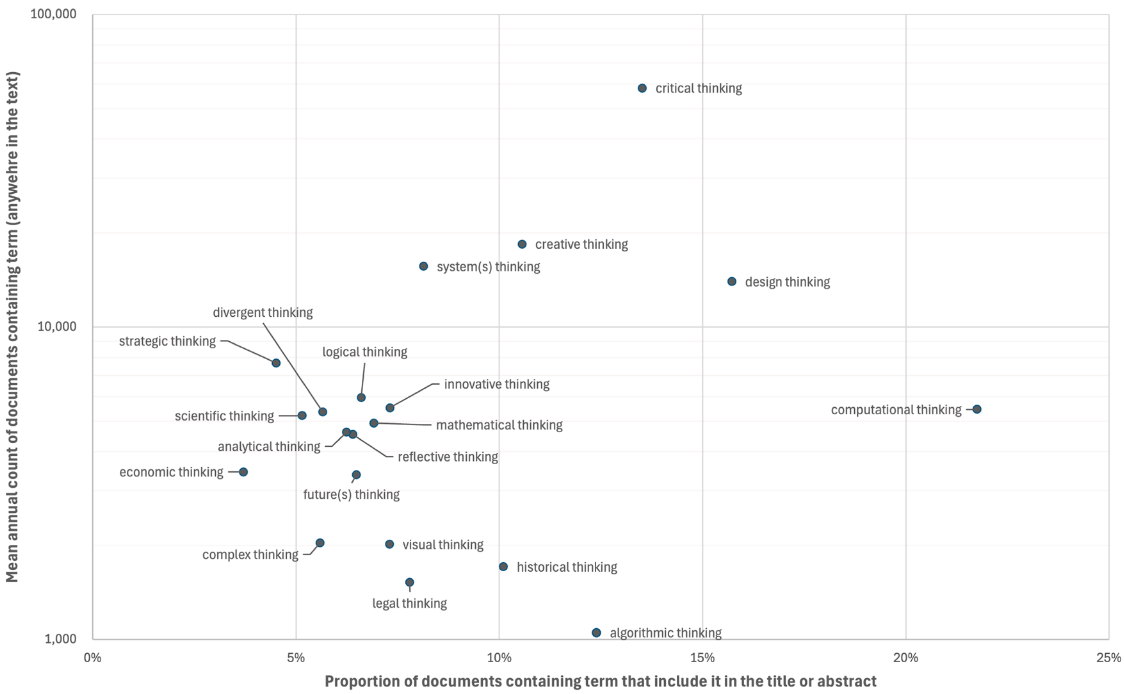

Fig. 6. Scatter plot showing the prevalence and prominence of 20 ways of thinking. Source: Dimensions database: full text search (both axes); title-abstract search (horizontal axis); date range from 1 January 2020 to 31 December 2024.

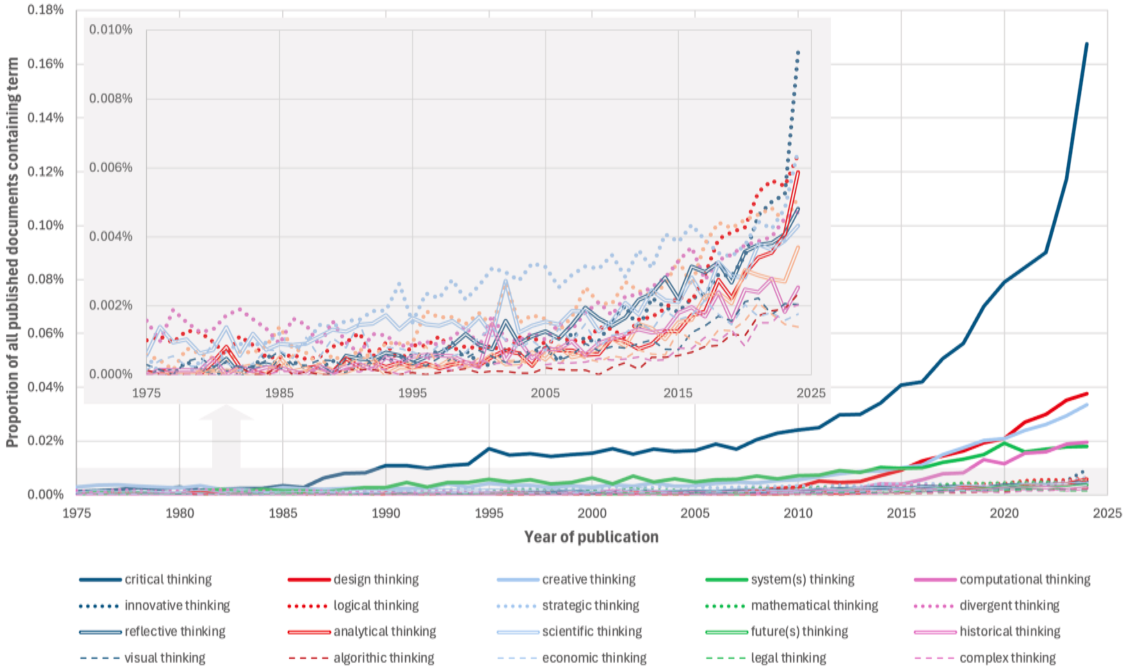

Fig. 7. Line graph showing the relative prevalence trends for 20 ways of thinking over five decades. For each year, the prevalence is presented as the proportion of all documents published that contain each term. For clarity, the inset omits the top five ways of thinking and uses an expanded vertical scale (the horizontal scale is compressed). Dimensions database: title-abstract search; date range from 1 January 1975 to 31 December 2024.

critical thinking (15.72 % and 13.52 %, respectively). In contrast, only 3.71 % of documents referring to economic thinking do so in the same locations, and comparable proportions were found for scientific thinking and strategic thinking (5.15 % and 4.51 %, respectively). These proportions are not correlated with the prevalence of the terms in the full text: $r(18) = 0.33, p = .15$. This means that this result cannot be explained by claiming that popular or well-established terms are more often used incidentally.

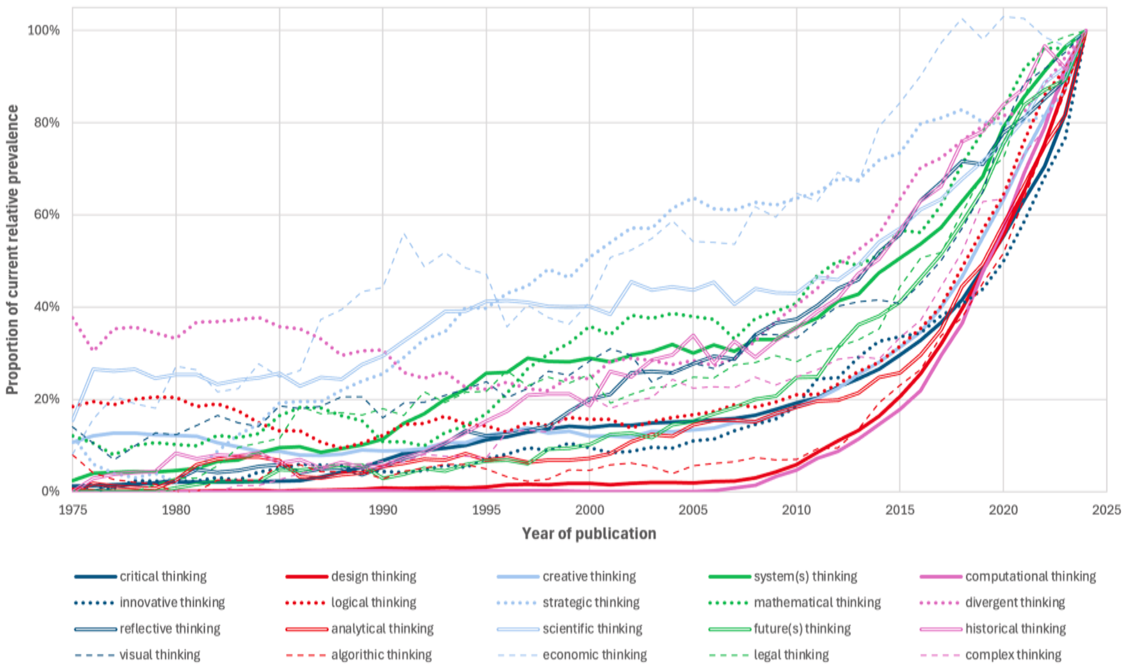

Fig. 8. Line graph showing the normalised relative prevalence of the top 20 ways of thinking over five decades (normalised against their relative prevalence in 2024). Source: Dimensions database: title-abstract search; date range from 1 January 1975 to 31 December 2024; data smoothed with a five-year rolling average (mean), but with 1-, 2-, 3- and 4-year averages for 1975, 1976, 1977, 1978, respectively.

4.4. Historical trends

To examine temporal trends for each way of thinking, the search window was extended to cover a 50-year period. To account for general publication trends (see Fig. 2), the count of documents for each way of thinking per year was divided by the total document count for that year, yielding the proportion of total documents referring to each way of thinking: "relative prevalence" (see Fig. 7). Notably, of the top 20 ways of thinking, critical thinking has the highest relative prevalence, exceeding 0.01 % in 1993 and 0.16 % in 2024. These proportions are far greater than those for other terms, none of which exceed 0.04 % at any point. However, when each way of thinking is examined in detail, similar upward trends can be observed (see Fig. 7 inset).

Considerable variation in each way of thinking's relative prevalence prevents easy comparison of their trends. To address this, the relative prevalence for each way of thinking in each year was divided by its current relative prevalence. This resulted in trend data representing each way of thinking's historical relative preference compared to its current relative preference. Plotting this normalised time series data permits the shapes of the trend lines for each way of thinking to be better compared (see Fig. 8). Notably, some ways of thinking have risen slowly, acquiring over 20 % of their current relative prevalence over 40 years ago (e.g. divergent, scientific and economic thinking). In contrast, others have only risen more recently, acquiring the same proportion of their current relative prevalence just 10 years ago (e.g. computational, algorithmic and design thinking).

4.5. Co-occurrence of terms

The preceding analyses consider each term separately, but terms might also be combined or contrasted. To examine the prevalence of co-occurrence for each of the top 20 ways of thinking within documents, each pair of terms was searched for in combination in the title and abstract (using the Boolean AND operator). The highest mean annual count of such co-occurrences was for critical thinking and creative thinking (236 documents/year), followed by critical thinking and systems thinking (95), and then creative thinking and divergent thinking (60). There were many pairs of terms for which no co-occurrence was identified, such as systems thinking and

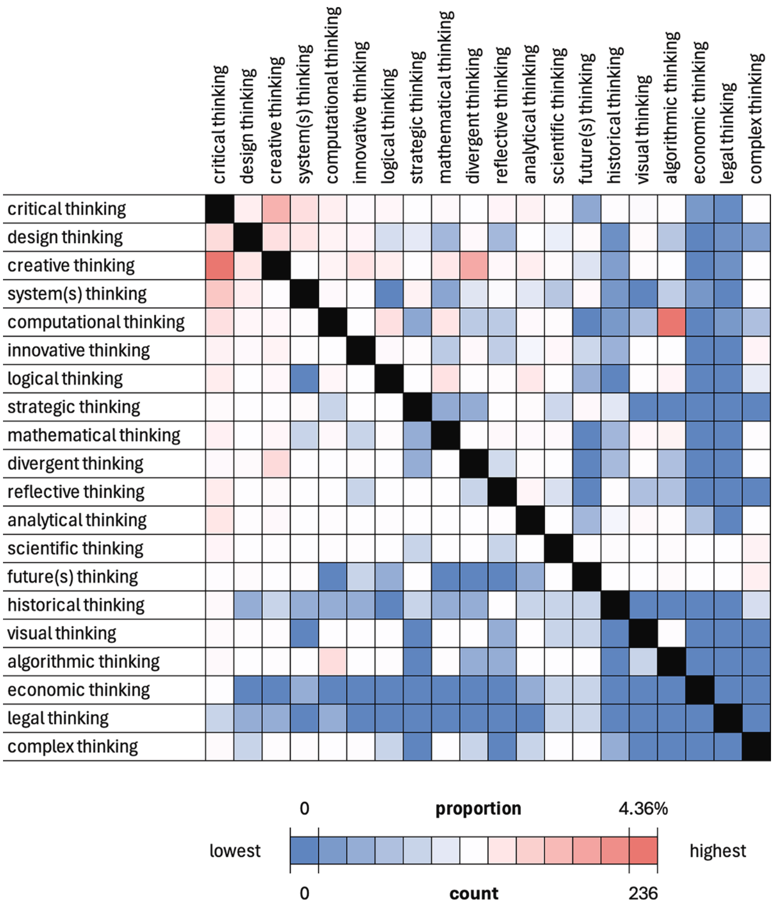

Fig. 9. A pair of triangular matrix heatmaps illustrating the frequency of term co-occurrences for 20 ways of thinking. Each cell in the lower triangle represents the mean annual count of documents including both terms (ranging from 0 to 236 documents). Each cell in the upper triangle represents the proportion of documents that include either term that include both terms (ranging from 0 to 4.36 %). Each triangle is independently coloured. Dimensions database: title-abstract search; date range from 1 January 2020 to 31 December 2024.

logical thinking. A heatmap representing the counts of documents for all possible term pairs is provided in Fig. 9 (lower triangle).

To account for the varying prevalence of each term, say term X and term Y, the number of documents referring to *both* terms X *and* Y was divided by the number of documents referring to *either* term X *or* Y. The highest such proportion was for computational thinking and algorithmic thinking (4.36 %), followed by creative thinking and divergent thinking (2.76 %), and then critical thinking and systems thinking (2.46 %). A heatmap representing these proportions for all possible term pairs is provided in Fig. 9 (upper triangle). Examining cell pairs that are symmetrically arranged about the matrix diagonal permits comparison of the counts and proportions for any term pair. For example, critical-creative has the highest count but not the highest proportion; computational-algorithmic has the highest proportion but not the highest count. However, there is a strong positive correlation between counts and proportions: $r(188) = 0.67$, $p < .001$.

The lower-right corner of Fig. 9 includes a cluster of term pairs with low levels of co-occurrence, both for document counts and document proportions. Many of these document counts are zero, so the relevant proportions are also indicated as zero. The columns and rows for economic thinking and legal thinking represent very low levels of co-occurrence with all other terms (except for scientific thinking and futures thinking). In fact, economic thinking and legal thinking each have no term co-occurrence with most of the other terms considered here (throughout the five-year sampling window).

4.6. Distribution across disciplines

For each way of thinking, references to the relevant term might be concentrated within just a few disciplines or might be more evenly distributed across many disciplines. To provide a measure of this distribution, the more inclusive full-text search was used to review documents where the terms are used but are not necessarily prominent. The relevant documents for the top 20 ways of thinking were counted according to their association with the 34 UoAs (see Section 3.5).

"Education" (UoA C23) was the discipline with the highest concentration of the relevant term for half of the top 20 ways of thinking. For example, 11.40 % of Education documents refer to critical thinking, 3.17 % refer to creative thinking and 1.29 % refer to computational thinking. Other disciplines occupy that first position for other ways of thinking (e.g. "Art and Design" for design thinking at 4.72 %; "Architecture, Built Environment and Planning" for systems thinking at 1.12 %). For most ways of thinking, after the discipline with the highest concentration of documents, subsequent disciplines exhibit relatively low concentration levels (see Fig. 10).

As with the temporal trends, any non-normalised analysis of disciplinary distribution is dominated by those ways of thinking with the highest prevalence (e.g. critical thinking). To account for this, the number of documents returned for each term across each discipline was normalised against the number of documents returned for each same term in the discipline in which it is most concentrated (Fig. 11). This permits a comparative representation—for each way of thinking—of how the concentration of relevant

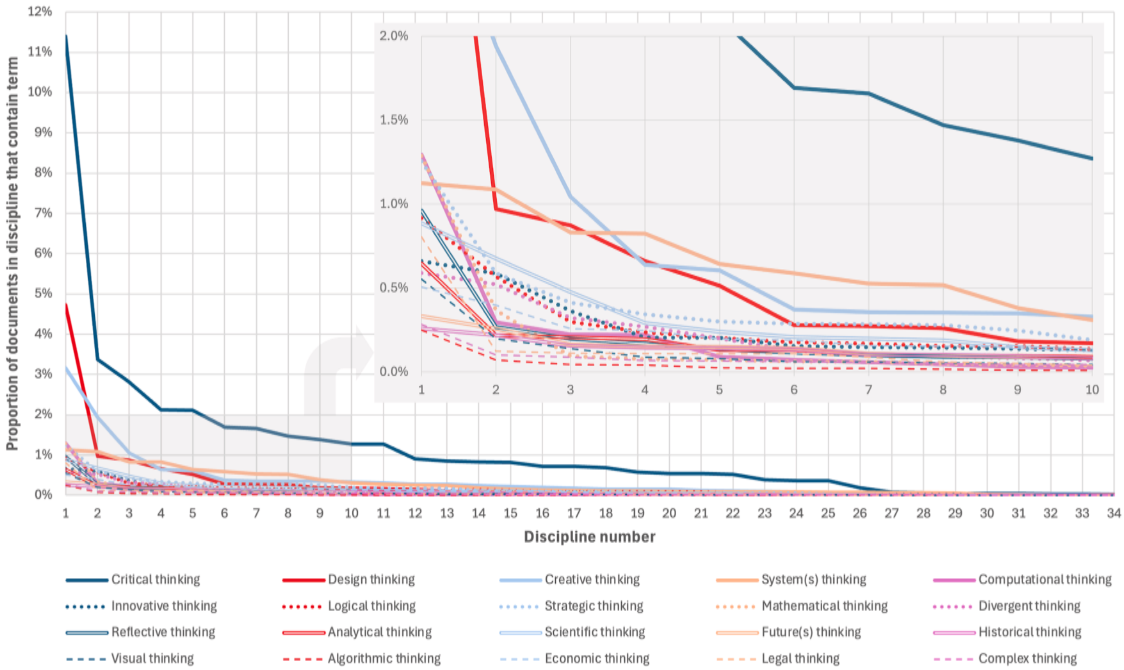

Fig. 10. Line graph showing the proportion of documents in 34 disciplines that refer to each of 20 ways of thinking. The disciplines are ordered from that with the highest term concentration (1st) to that with the lowest term concentration (34th). For each way of thinking, the list of disciplines numbered from 1 to 34 is unique (see Fig. 11). For clarity, the inset uses expanded vertical and horizontal scales. Dimensions database: full text search; date range from 1 January 2020 to 31 December 2024.

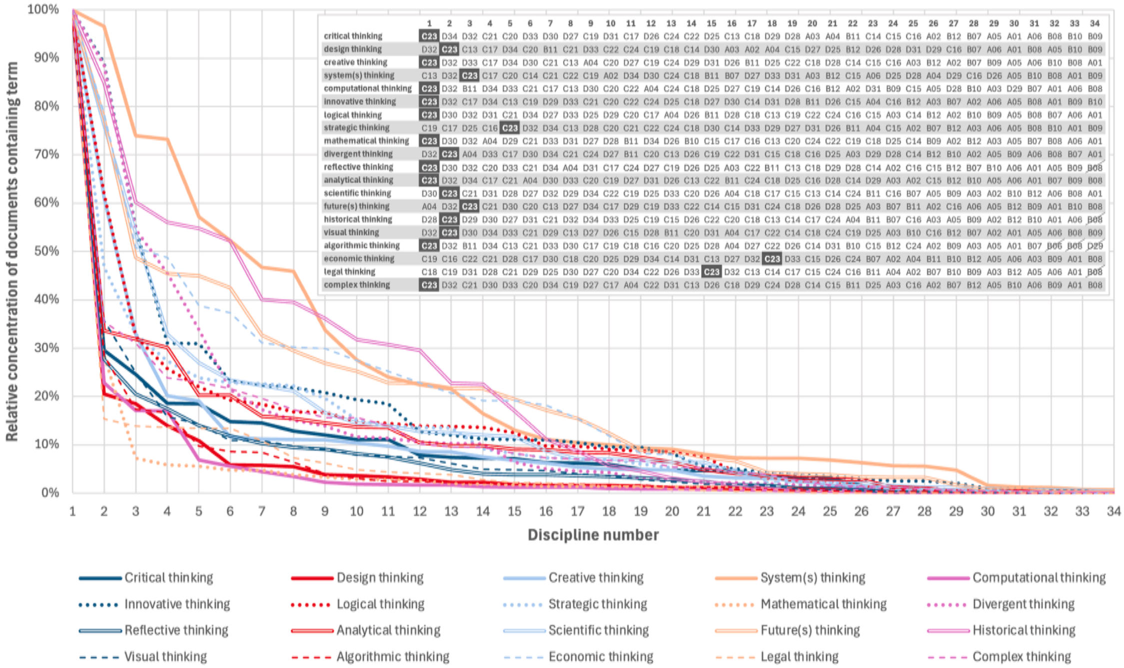

Fig. 11. Line graph showing the normalised concentration of 20 ways of thinking across different disciplines (normalised against the concentration level for each way of thinking in its first discipline). The disciplines are ordered from that with the highest term concentration (1st) to that with the lowest term concentration (34th). The inset lists the disciplines for each way of thinking: cells for Education (C23) are highlighted; cells with zero values are crossed out. Dimensions database: full text search; date range from 1 January 2020 to 31 December 2024.

documents falls away as we move beyond the discipline with the highest concentration (the first discipline). For example, by their third discipline, some ways of thinking still retain over 60 % of the concentration level found at their first discipline (systems thinking and historical thinking). For others, the comparable retention is less than 20 % (e.g. design thinking and computational thinking). For all ways of thinking examined here, this reduction to 20 % or less is found by or before the fifteenth discipline. Systems thinking is notable for exhibiting a relatively high concentration level across multiple disciplines. It has a concentration level of 1.12 % in its first discipline ("Architecture, Built Environment and Planning") and retains more than half that concentration level across the next five disciplines ("Art and Design"; "Education"; "Business and Management Studies"; "Social Work and Social Policy"; "Geography and Environmental Studies").

To quantify how evenly spread each way of thinking is across various disciplines, it is useful to establish a single measure of disciplinary distribution, such as 1-*Gini* (see Section 3.7). As already noted, the discipline of Education has the highest concentration of relevant documents referring to ten of the 20 ways of thinking considered here (see Fig. 11). For the other ways of thinking, Education is typically the second or third discipline (when sorted by concentration levels). Only for economic thinking and legal thinking does Education occupy a much less prominent position (18th and 15th, respectively). The high concentration of documents referring to ways of thinking in Education renders most ways of thinking less evenly distributed than when only considering their distribution beyond Education. To address this, 1-*Gini* values were recalculated with Education removed from the analysis, leaving 33 disciplines rather than 34 (see Fig. 12). This shows, for example, that whether or not Education is included, some ways of thinking are very evenly distributed across disciplines, such as systems thinking and futures thinking. Others are highly concentrated within disciplines, such as design thinking and legal thinking (again, whether or not Education is included). Notably, the closely related concepts of computational thinking, algorithmic thinking and mathematical thinking are among those that are the most affected by the exclusion of Education, an exclusion which substantially increases their measure of distribution equality.

4.7. Distribution across applications

To examine potential application areas for each way of thinking, documents were counted according to their association with the 17 SDGs (see Section 3.6). Again, the more inclusive five-year full-text search was used to measure how widely distributed the terms were, even if those terms did not occupy prominent document locations.

Of the 1,583,255 documents per year classified as relevant to one or more SDGs, the term critical thinking was found in more documents than the other ways of thinking (25,813 documents/year, 1.63 %), followed by creative thinking (7,029, 0.44 %) and systems thinking (6,875, 0.43 %). Across the SDGs, there was considerable variation in the proportions of documents containing terms

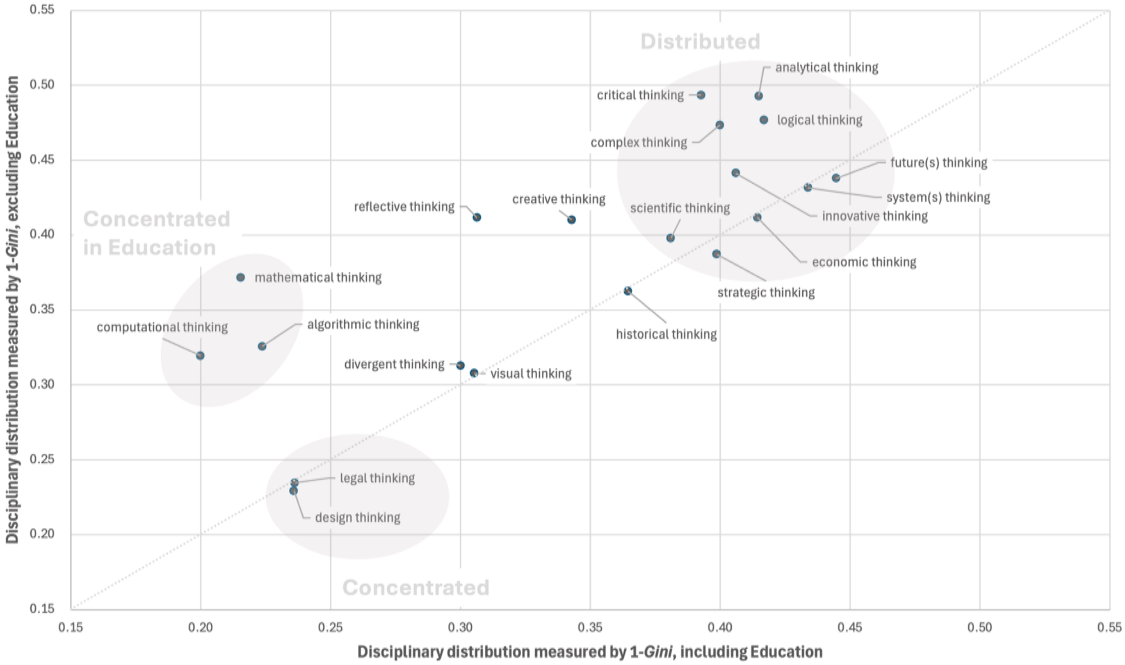

Fig. 12. Scatter plot of the disciplinary distribution (1-*Gini* values) for 20 ways of thinking, including and excluding Education (C23). The diagonal line represents equality of both values. Points positioned above that line have a higher measure of disciplinary distribution when Education is removed from the analysis. Dimensions database: full text search; date range from 1 January 2020 to 31 December 2024.

related to the 20 ways of thinking. The highest mean proportions were found in SDG 4 ("Quality Education," 1.23 %), then SDGs 9 and 17 ("Industry, Innovation and Infrastructure," "Partnerships for the Goals," both 0.39 %); the lowest mean proportion was found in SDG 7 ("Affordable and Clean Energy," 0.03 %).

Any non-normalised analysis of distribution might be skewed towards those document categories which are the largest (i.e. SDG 3:

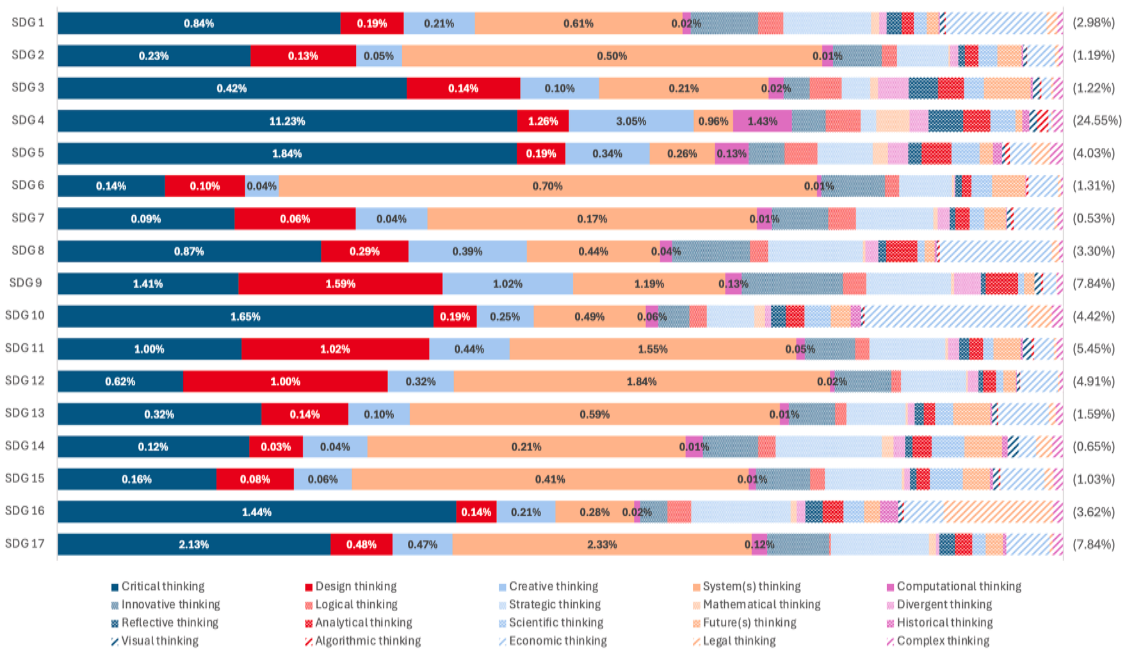

Fig. 13. Stacked bar graph showing the proportions of SDG-relevant documents associated with 20 ways of thinking. Numerical values are provided for the top five ways of thinking. The sum of all 20 proportions is provided in brackets to the right of each bar stack, indicating the scale for that stack, which is different for each SDG. Dimensions database: full text search; date range from 1 January 2020 to 31 December 2024.

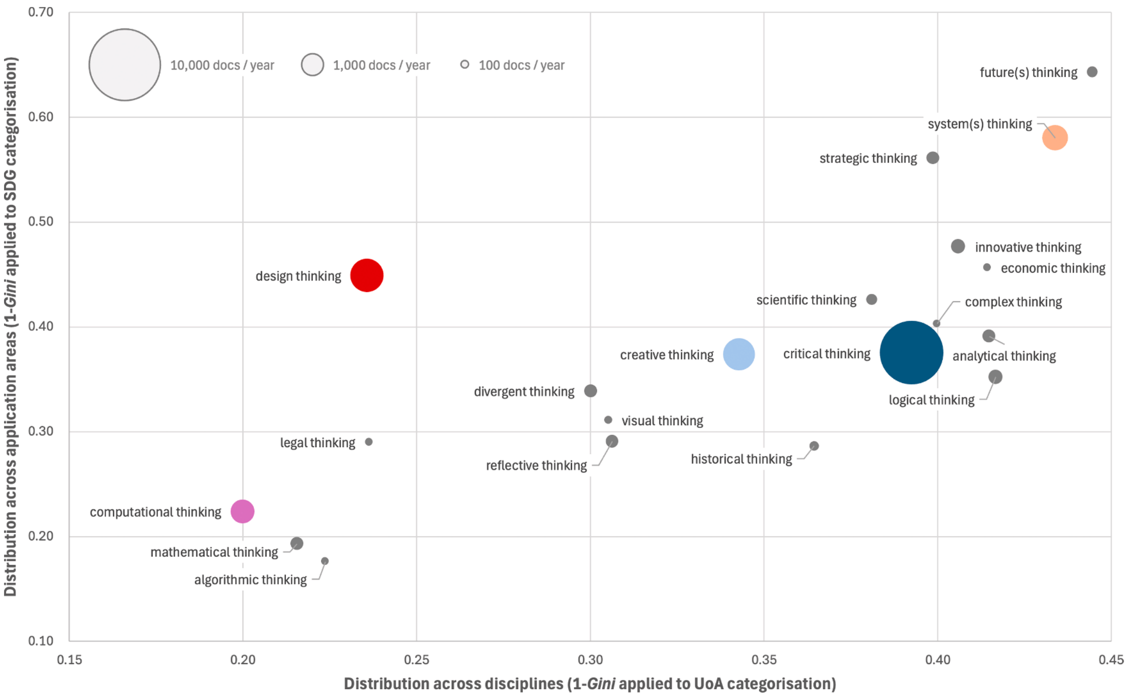

Fig. 14. Scatter plot showing the distribution across disciplines and application areas for 20 ways of thinking. Dot area is proportional to the prevalence of each way of thinking. The colours of the top five ways of thinking are consistent with previous charts. Dimensions database: full text search (prevalence); title-abstract search (distributions); date range from 1 January 2020 to 31 December 2024.Discussion.

"Good Health and Well Being," see Table 3). Accordingly, Fig. 13 represents the proportions of each SDG's documents that refer to each way of thinking. Critical thinking is still the most prevalent way of thinking in this analysis, but is now followed by systems thinking then creative thinking (averaging 1.44 %, 0.75 % and 0.42 %, respectively, across all SDGs). Critical thinking in SDG 4 stands out, with the term appearing in 11.23 % of documents. The next highest proportions are found for creative thinking in SDG 4 (3.05 %), systems thinking in SDG 17 (2.33 %) and critical thinking in SDG 17 (2.13 %).

Note that SDG 4 (Quality Education) covers a similar topic to UoA C23 (Education), which was already discussed (Section 4.6). Just as with UoA C23, many of the documents associated with SDG 4 are related to the various ways of thinking considered here. In fact, most of these ways of thinking (15 of the 20) have their highest concentration level in SDG4 documents asso SDG 4 (e.g. 11.23 % for critical thinking, 3.05 % for creative thinking and 1.43 % for computational thinking). These concentrations are similar to those for UoA C23 (11.40 %, 3.17 % and 1.29 %, respectively). However, the collections of documents associated with SDG 4 and UoA C23 are not identical. In the five-year window reviewed here, SDG 4 has 166,789 documents per year associated with it, compared to 213,558 for UoA C23.

To quantify how evenly spread each way of thinking is across the SDGs, the same single measure of distribution was used: 1-*Gini*. Having examined the distribution of each way of thinking across both disciplines (UoAs) and application areas (SDGs), a combined representation of these distributions can be constructed (see Fig. 14). Of the most prevalent ways of thinking, systems thinking stands out as being the most evenly distributed across both disciplines and application areas. Design thinking stands out for being more evenly distributed across application areas than across disciplines; the remainder have more similar 1-*Gini* scores for these two measures. Overall, there is a strong positive correlation between the 1-*Gini* values for the UoAs and SDGs: $r(19) = 0.75$, $p < .001$.

5. Discussion

To examine the prevalence and distribution of different ways of thinking, a comparative bibliometric analysis was conducted. Specifically, seven research questions were addressed in turn (see Sections 4.1 to 4.7). In doing so, this study focused on many ways of thinking, which contrasts with prior studies, which have generally made isolated claims about publication counts and publication trends for only one way of thinking at a time, such as critical thinking (Pagán Castaño et al., 2023), creative thinking (Park & Lee, 2022), design thinking (Leal Filho et al., 2024), systems thinking (Hossain et al., 2020) and computational thinking (Chen et al., 2023). Where prior comparative analyses have been offered, they have been quite limited. For example, reports on prevalence and co-occurrence offered by Crilly (2024) only account for a few ways of thinking and omit important non-disciplinary approaches, such as critical thinking and creative thinking (pp. 10, 44). By ranking 78 ways of thinking to identify the top 20, this present article has established a more wide-ranging and transparent basis for its focus. However, of the 20 terms studied, economic thinking and legal thinking appear as outliers because neither term shares common suffixes with the others (Fig. 5), neither term exhibits much co-occurrence with the others (Fig. 9) and neither term is strongly associated with the discipline of Education (see Fig. 11, inset). Consequently, the remaining discussion omits these two ways of thinking.

5.1. Prevalence

Previous bibliometric studies have made claims about the increasing prevalence of individual ways of thinking. However, the data have generally not been normalised (against general publication rates), and the analyses have been non-comparative (in relation to other ways of thinking). Examples include independent studies of critical thinking (Dong et al., 2023, p. 4), design thinking (Bhandari, 2023, p. 3105), systems thinking (Hossain et al., 2020, p. 9) and computational thinking (Chen et al., 2023, p. 4). The analyses presented here confirm that even when normalised against general publication rates, each of these ways of thinking trends upwards (see Fig. 7). This might be explained by a general drive for educators and employers to recognise the importance of thinking skills over domain knowledge in contexts where continual change demands adaptability and continuous learning (e.g. see Dumitru & Halpern, 2023; Li, 2025).

Although upward trends in relative prevalence were observed across all ways of thinking, not all those trends look the same. The trends for critical thinking and systems thinking can now be distinguished from those for design thinking and computational thinking: the former pair have slowly risen to prevalence compared to the more recent and steeper rise exhibited by the latter pair (see Fig. 8). Other ways of thinking have trends that lie between these extremes. One factor that might influence the perception of prevalence is the frequency with which key terms occupy prominent locations within documents, which has now been shown to vary considerably between different ways of thinking (see Fig. 6), indicating variation in whether these concepts are more central or more incidental to the published work. This fits with studies on other topics, where the centrality of concepts changes over time. Examples include studies of the bioeconomy (Mougenot & Doussoulin, 2022, pp. 1041, 1044), the health metaverse (Wu et al., 2024, p. 133) and user accessibility (Draux et al., 2025, p. 29).

Comparative claims about the prevalence of ways of thinking are seldom made. The only known quantitative ranking of the relevant terms employed a search window from 1954 to 2023 (Crilly, 2024, p. 10). That analysis resulted in a representation where systems thinking was more prevalent than design thinking. However, as we have seen, this kind of extended search window skews the results toward terms that have a long history, such as critical thinking and systems thinking (Fig. 7). Restricting searches to a more recent time window emphasises current prevalence over historical prevalence, placing design thinking ahead of systems thinking (see Fig. 4).

One other prior claim about comparative prevalence is Kelly and Gero's (2021) observation that design thinking and computational thinking are the only two ways of thinking to become prevalent since the year 2000. This present article confirms that they do indeed have high levels of current prevalence (see Fig. 4) and that this prevalence was obtained quite recently (see Fig. 8). While other ways of thinking have obtained higher levels of prevalence (e.g. critical thinking, creative thinking), such prevalence has been developing over longer periods. Algorithmic thinking has also obtained its prevalence quite recently but has not obtained the same level as either design thinking or computational thinking. As such, Kelly and Gero's claim can be substantiated with the analyses reported here, and any other such claims could now similarly be assessed.

All these discussions of prevalence—and those of distribution, below—should be interpreted in light of the suffixes commonly appended to each way-of-thinking term (see Fig. 5). Each of these terms is used to refer to a family of related concepts, where the word "thinking" is preceded by the name of a discipline or style (e.g. critical, creative, design) and is followed by reference to what the thinker possesses or does (e.g. ability, skill, process). Previous studies have observed the many meanings assigned to individual ways of thinking (e.g. Kaur & Craven, 2022; Kimbell, 2011), but this might be the first quantification and representation of how such meanings are distributed. It usefully illustrates that some terms are used quite consistently (e.g. critical thinking, systems thinking), while others are commonly used with multiple meanings (design thinking, mathematical thinking). Bibliometric analyses and other studies should be considered in light of this.

5.2. Distribution

It is a characteristic feature of the discourse surrounding many ways of thinking that they are each promoted as widely relevant, whether to different disciplines or situations. These claims are sometimes explicit in a single work, such as Pressman's (2018) observation that design thinking can be applied across many disciplines, such as politics, business, health, science and law (pp. xvii–xviii). Similar claims can be developed from assembling multiple works that individually examine the application of a way of thinking across disciplines, such as the application of design thinking in business (Liedtka et al., 2013), healthcare (Roberts et al., 2016) and policy (McGann et al., 2018). Related arguments can be identified or assembled for many other ways of thinking, but this would still not result in comparative assessments across different ways of thinking. We might wonder, for example, if design thinking is more widely discussed than systems thinking, or vice versa, and whether the application areas are the same or different. The present article answered such questions, quantifying how ways of thinking are distributed across disciplines and application areas (see Figs. 10–14). For example, various UoAs and SDGs were found to have relatively high proportions of documents referring to design thinking, but still higher proportions were found for critical thinking and systems thinking.

When ways of thinking are combined into sets, those sets are claimed to be of broad relevance, either across or within disciplines and application areas. Prominent examples include the World Economic Forum's three-part set (creative thinking, systems thinking and analytical thinking) and the European Commission's five-part set (systems thinking, futures thinking, values thinking, critical thinking and strategic thinking). However, when sets like these are proposed (see Fig. 1 for other examples), no explicit justification is necessarily offered for those ways of thinking that have been included or excluded. In any case, it would be difficult to identify any prior basis for such justifications. The present article can help with this, permitting ways of thinking to be assessed according to their distribution across two different categories. For example, critical thinking, creative thinking and systems thinking are not only among the most prevalent ways of thinking, they are also some of the most evenly distributed across disciplines and application areas (see Fig. 14). This might offer a starting point for developing sets of ways of thinking, but if so, it should be followed by assessing any overlaps between them and gaps that remain, issues this study has not examined.

5.3. Limitations and further work

The work reported here is wide-ranging but still exhibits features that compromise our ability to generalise the findings. Some key limitations are now discussed, along with suggestions for further work to address them.

First, this study was primarily based on counting the documents that use specific terms within certain periods or categories. To evaluate the quality of the results, a random sample was manually reviewed across five different ways of thinking (see Section 3.3). This review could be extended to include more ways of thinking, more search queries and more documents. However, even if search results are verified as including terms that refer to the relevant concepts, these concepts can be interpreted in different ways. The suffix analysis provides some insight into this (see Section 4.2), but is limited to the most common suffixes. Even for those terms that have the highest proportion of documents invoking these suffixes (creative thinking, critical thinking and visual thinking), that proportion does not reach 50 %. Various other meanings might be implicit in documents, or explicitly indicated without the use of suffixes. To explore this, future work could usefully employ semantic analyses to develop insights into how the terms are being interpreted and applied. This could include corpus linguistics and discourse analysis, either performed manually or using software tools (for a recent comparison of available tools, see Moreno-Ortiz, 2025). Either way, semantic analysis would allow each way of thinking to be subdivided according to different schools, traditions or factions, permitting a separate treatment of each. Semantic analyses focused on sentiment could also identify critical or dismissive interpretations of the relevant terms, distinguishing between the prevalence of terms and the popularity of concepts (for specific methods, see Wankhade et al., 2022).

Second, this study treated each term separately, even though close relationships can be identified between some of them. For example, terms with common roots might point to overlapping concepts, such as systems thinking, systemic thinking and systematic thinking (see Table 1). We might also identify overlaps between seemingly similar concepts labelled with terms that do not share common roots, such as critical thinking and logical thinking, or design thinking and creative thinking, or computational thinking and algorithmic thinking. Prior work has mostly examined relationships between ways of thinking that are quite distinct, such as design, systems and entrepreneurial thinking (Patel & Mehta, 2017), or those three and computational thinking (Crilly, 2024, p. 63). Relationships between similar ways of thinking have not attracted the same attention. Future work could usefully identify overlapping ways of thinking and group them for aggregated comparisons, whether through bibliometric analysis or other methods. For example, collections of ways of thinking that support generation, production or change (e.g. design thinking, entrepreneurial thinking) could be compared with ways of thinking that support identification, comprehension and distinction (e.g. scientific thinking, historical thinking).

Third, this study has focused on a restricted range of terms expressed in the English language. Although the initial list of terms was large in comparison to prior work, that list only included terms that conformed to the format "*[variant]* thinking." There are many other related terms that could be included that do not follow this convention. Bibliometric analyses of such adjacent terms are already available, such as those focused on creativity (Hernández-Torrano & Ibrayeva, 2020), problem posing (Cansiz Aktas, 2022) and entrepreneurial mindset (Osmanovic, 2025). There is scope for further comparative bibliometric analyses that are more focused on specific ways of thinking but less restricted in the format of the terms used to refer to them. For example, such an analysis might focus only on generative or change-oriented ways of thinking (including concepts related to creativity, design and innovation), but include any terms that describe them, irrespective of term structure or format.

Fourth, this study searched a database focused on research publications, but the range of documents was quite broad, including articles, proceedings and seminars (see Section 3). While this might provide a general understanding of how often the relevant terms are used in research, it fails to distinguish between the discourses playing out in different locations and does not prioritise some document types over others. Similarly, beyond research, it would be useful to explore how other communities use identical or similar terms, communities relevant to issues of concept prevalence and distribution. Examples of other document categories that might usefully be searched include popular books, policy briefings, curriculum specifications, news reports and business articles. Further work could examine these documents, permitting not only comparisons across ways of thinking, but also across communities of practice. Although no relevant work like this was found, some insights might be gained from the methods applied to other analyses of social media sites (e.g. Russell, 2011) and policy document repositories (e.g. Szomszor & Adie, 2022).

Fifth, even without expanding the study in the ways described above, there are still various limitations to the specific analyses reported here. Temporal trends could be analysed not just to understand changes in overall prevalence, but also to investigate the origin and development of the relevant concepts. Such bibliometric analyses of concept evolution have been performed for other relevant topics, such as educational scaffolding (Lin et al., 2022, p. 6) and design cognition (Ata & Doğan, 2025, pp. 14–16). Another valuable extension would be to examine how three or more terms co-occur within documents, disciplines and application areas (for an example limited to four ways of thinking, see Crilly, 2024, p. 44). Finally, attention could be focused on specific documents and authors, examining their influence through citation and co-citation analyses (again, for a limited example, see Crilly, 2024, Appendix B).

Whether future studies assume a broader or narrower scope, the work reported here provides a basis for identifying the kinds of comparative questions that might be asked and the kinds of comparative analyses that might be performed.

6. Conclusions

Flexibly employing different ways of thinking is valuable to personal growth and professional success. They have consequently attracted the attention of individuals and institutions responsible for developing and delivering education and training. Although each way of thinking has most often been considered in isolation, they are sometimes collected into sets promoted as collectively valuable. Whether working on individual ways of thinking or sets of them, there are important questions we must ask about which ones to focus on and why. This study has addressed these questions from a bibliometric perspective, permitting analyses of many ways of thinking over many years and many documents. The findings differentiate ways of thinking according to their prevalence and distribution, something not previously reported. This permits researchers and practitioners to identify which ways of thinking are gaining the most attention and where that attention is located. This can help those focused on ways of thinking to more effectively identify, select, prioritise and combine them.

CRediT authorship contribution statement

Nathan Crilly: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization.

Declaration of competing interest

The author declares no competing interests.

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Data availability

The data analysed in this article are available from the University of Cambridge data repository: https://doi.org/10.17863/CAM.121190.

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