BMC Psychology

RESEARCH Open Access

The 8-Factor reasoning styles scale: development, validation, and psychometric evaluation

Volkan Duran[1*] and Ferdi Çelık[2]

Abstract

Background Building on Hacking's historical-philosophical notion of "styles of reasoning" and subsequent three-axis formalisation (Disposition, Perception, Organization), this study develops and validates the *Eight-Factor Reasoning Styles Scale* (8-FRSS). The instrument operationalises eight theoretically predicted styles that arise from the orthogonal intersections Empirical ↔ Hypothetical, Metaphorical ↔ Analogical, and Inductive ↔ Deductive.

Methods Items (5 per style; 40 total) were generated from the Reasoning Style Model, vetted by five measurement experts, and refined through a pilot face-validity study ($n=50$). A sequential mixed-methods design followed: (1) Exploratory Factor Analysis (EFA; $n=441$); (2) Confirmatory Factor Analysis (CFA-1; $n=316$) with DWLS on polychoric correlations; (3) cross-validation CFA-2 on an independent community sample ($n=604$). Reliability (α, ω) and composite reliability/AVE were computed, and concurrent validity was assessed against the Turkish adaptation of the Sternberg–Wagner Thinking Styles Inventory (TSI-TR; 13 subscales).

Results The EFA revealed the theorised eight-factor solution after removal of two items, explaining 58.2% of variance (KMO = 0.932; Bartlett $p<.001$). CFA-1 showed excellent fit (χ^2/df = 1.77, CFI = 0.918, TLI = 0.901, RMSEA = 0.052, SRMR = 0.047) after minor item pruning; CFA-2 replicated adequate fit in the broader sample (CFI = 0.897, TLI = 0.877, RMSEA = 0.057, SRMR = 0.048). Six subscales met reliability standards (ω/0.70–0.77); two (Hypothetical-Deductive, Empirical-Inductive) showed marginal values (ω = 0.48–0.69), earmarked for revision. Total-scale reliability was high (ω = 0.93; α = 0.91). Convergent evidence came from significant positive correlations with conceptually matched TSI-TR subscales, strongest for Analogical styles with legislative/executive/judicial thinking ($r\approx .51$–0.61, $p<.01$).

Conclusions The 8-FRSS provides the first psychometrically robust measure that simultaneously captures empirical–hypothetical orientation, metaphorical–analogical framing, and inductive–deductive organisation. Its factorial stability across student and community samples, coupled with satisfactory reliability and demonstrable concurrent validity, supports its use in educational, cognitive, and decision-science research. Future work should refine lower-reliability factors, test longitudinal invariance, and explore predictive links to learning outcomes and susceptibility to misinformation.

Keywords Reasoning styles, 8-FRSS, Factor analysis, Content validity, Reliability, Concurrent validity

*Correspondence:
Volkan Duran
volkan.duran8@gmail.com
[1]Psychology Department, Iğdır University, Samsun, Turkey
[2]Ondokuz Mayıs University, Samsun, Turkey

Background

A style of reasoning refers to a model of inferential relationships that underlines the selection, interpretation, and support for evidence toward scientific conclusions or particular phenomena [1]. The concept can be categorized in different ways. In the narrow sense, a style of reasoning offers knowledge transfer procedures peculiar to some subfields that provide the ability to establish an inferential relationship within a research domain. However, in a more general sense, a style of reasoning configures what counts as true or false within its scope. Hacking's "Styles Project," as he refers to it in Language, Truth and Reason [2], represents the view that diverse scientific modes of knowing have been invented and stabilized in different historical periods. While he has elaborated his initial thoughts over four decades, he has not worked them out as a fully-fledged theory. Crombie initially viewed these "styles of thinking" as long-standing practices and conceptions of nature, which first emerged in ancient Greece and then developed uninterruptedly [3]. In Styles of Scientific Thinking in the European Tradition, he listed six: (1) a "postulational style" based on deductive proofs from axioms; (2) experimentation to test postulates; (3) constructing analogical models to reveal mechanisms; (4) taxonomic ordering by comparison; (5) statistical analysis of population regularities; and (6) historical derivation explaining the present as an outcome of the past. Hacking adds metaphysical depth to Crombie's notion, arguing that a style is more than a method of inquiry or reasoning and, more specifically, makes richly philosophical claims about how these styles shape our understanding [2, 4–7] Sciortino's paper provides a response to the problem of the identification and categorization of "styles of reasoning" introduced by Ian Hacking. Sciortino revisits Hacking's inability to account for a mechanism of telling what is to count as a style of reasoning and constructs a solution anchored in the prototype theory of categorization. This he does by providing the grounds that some styles, like statistical, algorithmic, and laboratory reasonings, form prototypes given their historical and cognitive importance. The paper suggests understanding styles of reasoning as a category with degrees of membership based on similarity to those prototypes. This approach is, in any case, congenial to Hacking's general philosophical outlook [8].

he philosophical discussion of styles of reasoning by authors such as Bueno, Crombie, and Hacking, therefore, provides the background necessary to appreciate how inferential practices, as a rule, fashion scientific inquiry and truth. Building on these insights, a new model can be proposed as a formal and systematic model that operationalizes these abstract notions. As the former insists on historical evolution and metaphysical depth, the latter introduces a practical framework for categorizing and analyzing reasoning processes through dimensions like disposition, perception, and organization. These perspectives together build a comprehensive view that bridges theoretical and applied approaches toward reasoning styles. In this respect, the Reasoning Style Model [9] was formed, which was then improved in later studies both as a model and a scale [10–15] (Fig. 1), providing an inference plane with four dimensions: representations, assumptions, resemblances, and appearances. A previously developed scale on reasoning styles offered an initial framework but did not address all the theoretically proposed dimensions of reasoning. This weakness prompted the need for a more comprehensive measure. To fill these gaps, the present study introduces and validates the 8-FRSS, which integrates three overarching dimensions:

1. Disposition: Empirical ↔ Hypothetical.
2. Perception: Metaphorical ↔ Analogical.
3. Organization: Inductive ↔ Deductive.

By combining these three axes, eight distinct reasoning styles emerge (e.g., Empirical-Deductive, Hypothetical-Inductive), and the key constructs are described in Table 1.

Incorporating the key constructs in Table 1, the diagram in Fig. 1 represents a three-dimensional reasoning model based on the 8-FRSS, integrating three fundamental axes: Disposition, Perception, and Organization. The Organization Dimension (vertical axis) distinguishes between Induction (generalizing from specific observations) and Deduction (applying general principles to specific cases). Positioned at the four corners of the induction diamond are the reasoning styles that emerge when inductive organisation intersects with different perceptual and dispositional poles: Sensorial (Empirical × Inductive), Classifier (Metaphorical × Inductive), Associative (Analogical × Inductive) and Predictive (Hypothetical × Inductive). Analogously, the deduction diamond hosts Perceptual (Empirical × Deductive), Imaginative (Metaphorical × Deductive), Attributive (Analogical × Deductive) and Intuitive (Hypothetical × Deductive). By locating each factor in this two-plane, cross-shaped field, the figure shows at a glance how eight distinct yet correlated reasoning profiles arise from orthogonal intersections of the three underlying cognitive axes, thereby justifying both the theoretical expectation and the empirical recovery of an eight-factor solution:

Predictive (Hypothetical × Inductive)

Predictive reasoners begin with mental simulations—"what-if" scenarios that are only loosely tethered to immediate data—and then look for patterns that will let

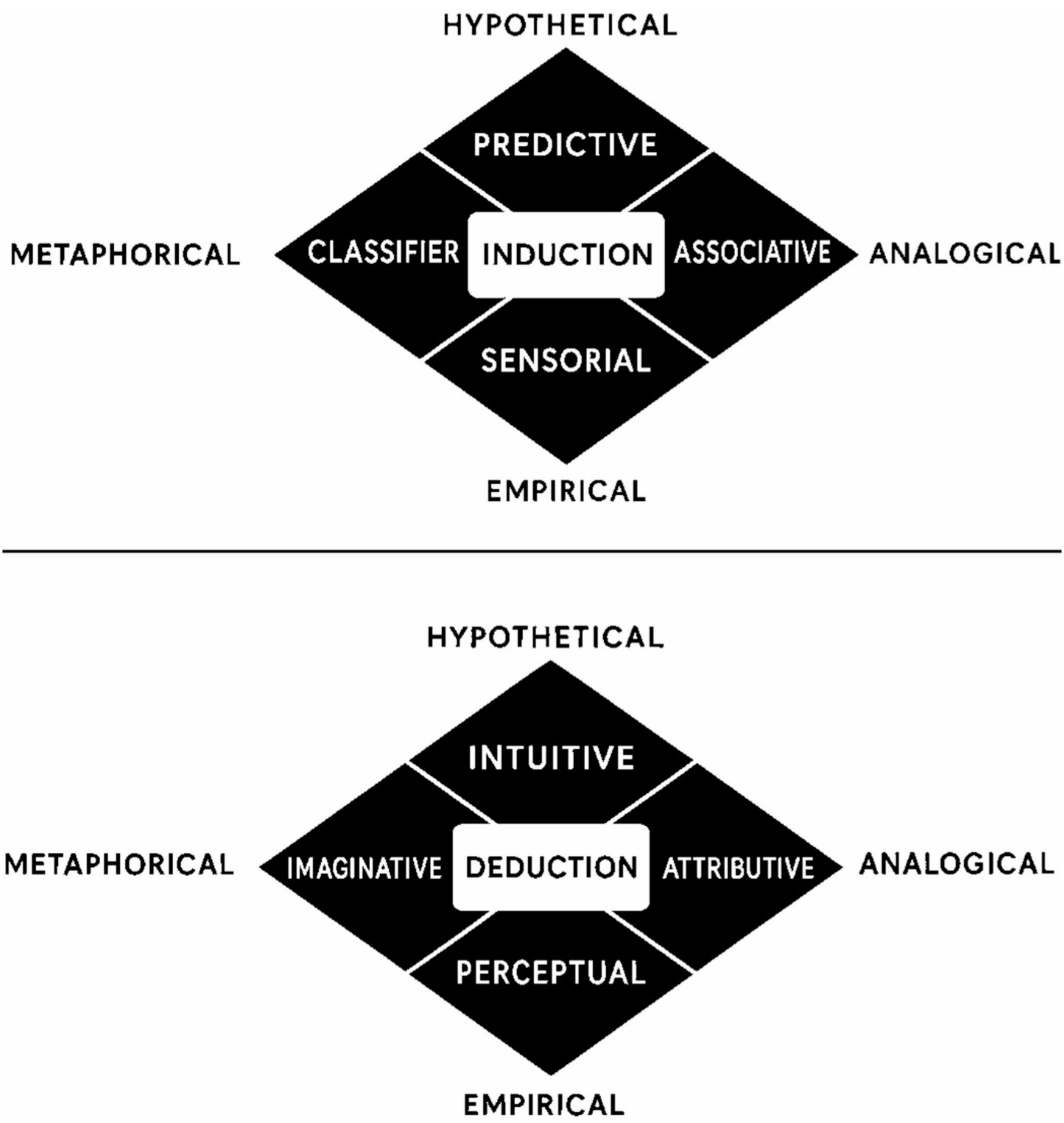

Fig. 1 Reasoning styles model

them generalise outward. They treat each imagined possibility as a provisional experiment, accumulate the regularities that recur across these simulations, and translate those regularities into probabilistic forecasts about the real world. In practice this style fuels activities such as scenario-planning, futures studies, and hypothesis-generation in exploratory science, where creative conjecture is systematically sifted for stable, generalisable signals.

Classifier (Metaphorical × Inductive)

Classifier reasoning turns to metaphor as a perceptual lens, using vivid, often image-laden comparisons to make sense of raw observations. The metaphors act like cognitive tags: they highlight salient features, group scattered instances under a shared symbolic banner, and let the thinker roll many particulars up into broader taxonomic categories. A biologist dubbing a newly seen behaviour a "mating dance," or a teacher likening student

Table 1 Key cognitive constructs in the reasoning framework

Term	Definition	Citation
Hypothetical thinking	The capacity to imagine alternative possibilities beyond the immediate facts by constructing mental models under specific premises.	[16]
Metaphorical reasoning	Mapping one conceptual domain onto another via systematic use of metaphors, grounded in embodied image schemas.	[17]
Analogical reasoning	Transferring structural resemblances between disparate domains to support inference, learning, and model building.	[18]
Empirical reasoning	Grounding knowledge in sensory-driven appearances, where concepts are represented through perceptual symbol systems.	[17]
Inductive inference	Generalizing from specific observations or data points to form broader hypotheses or general rules.	[19]
Deductive inference	Deriving particular predictions or conclusions from organized, higher-level representations or premises.	[20, 21]
Disposition axes	Cognitive and motivational factors, such as working-memory capacity, confidence, or caution that modulate how reasoning strategies are deployed.	[22]
Perception axes	Dimensions of sensory processing that shape how appearances are encoded into representations.	[17]
Inference plane	The conceptual continuum spanning inductive to deductive reasoning processes within a unified inferential framework.	[23]
Organization axis	The hierarchical ordering of representations and assumptions to optimize prediction and interpretation under active-inference or predictive-processing models.	[19]
Representations	Mental models or symbol systems that encode knowledge structures, allowing manipulation of concepts and relations internally.	[16]
Assumptions	Foundational premises or sampling beliefs that guide the generation and evaluation of hypothetical or inductive inferences.	[24]
Resemblances	Perceived similarities or alignments between entities or relations that enable analogical mapping and transfer.	[18]
Appearances	Observable features or surface characteristics of stimuli that feed into empirical representations and influence inference.	[17]

misconceptions to "conceptual knots," is engaging in this style—using figurative anchors to scaffold inductive leaps toward orderly classes.

Associative (Analogical × Inductive)

Associative reasoners scour cases for underlying structural resemblance. Once they spot a deep alignment—often invisible at the surface—they lift it into a rule that can be applied more widely. The hallmark of this style is bootstrapping: it hoists an insight from one domain into a more general form and then repurposes it elsewhere. Engineers who abstract the load-bearing logic of a spider's web into bridge design, or cognitive scientists who see neuronal wiring echoed in social networks, are reasoning associatively: they inductively generalise by tracing analogical skeletons.

Sensorial (Empirical × Inductive)

Sensorial reasoning is data-native. The thinker lets sensory or instrumental readings accumulate until patterns virtually declare themselves. Instead of imposing prior frames, the sensorial style listens to the "voice" of the data, clustering recurring traces and escalating them into empirical generalities. Field naturalists who catalogue species traits, or data journalists who mine thousands of social-media posts for emerging trends, exemplify this modus operandi—moving from concrete, often unvarnished particulars to bottom-up generalisations that remain tightly coupled to observation.

Intuitive (Hypothetical × Deductive)

Intuitive reasoners start from conjectural premises—bold theories, hunches, or axioms that may lack direct verification—then push them downward through deduction to yield crisp, testable predictions. Confidence comes not from evidence already in hand but from the coherence and generative power of the theoretical scaffold itself. Mathematicians positing an unproved lemma to explore its logical consequences, or physicists deducing phenomena from an elegant but as-yet-untested model, display this intuitive signature.

Imaginative (Metaphorical × Deductive)

Imaginative reasoning imports rich figurative frames—mythic archetypes, narrative motifs, conceptual metaphors—and treats them as generative templates. From the template's implicit logic, the thinker deduces specific implications for the case at hand. In ethics, invoking the "veil of ignorance" metaphor to derive equitable policy prescriptions, or in design thinking, using a "journey" metaphor to infer step-wise user needs, the imaginative style spins actionable conclusions out of figurative models.

Attributive (Analogical × Deductive)

Attributive reasoners take a well-understood source system, map its key attributes onto a target, and deduce what should follow if the mapping holds. This is case-based deduction: once the structural analogy is in place, concrete consequences cascade logically. A lawyer arguing that digital privacy should follow the same protections as postal mail, or an AI researcher porting insights from mammalian vision into convolutional networks, is reasoning attributively—deriving particular inferences by aligning shared attributes.

Perceptual (Empirical × Deductive)

Perceptual reasoning anchors itself in established rules or laws but insists that each deduction be cross-checked against sensory evidence. The thinker applies a principle, derives a specific expectation, and immediately seeks measurable confirmation or disconfirmation. Experimental physicists who validate equations through precise instrumentation, or clinicians who match textbook symptom chains with real-world diagnostics, embody the perceptual style: deduction disciplined, and constantly corrected, by observational feedback.

The Disposition Dimension (diagonal axis) differentiates Hypothetical reasoning (theoretical, assumption-based thinking) from Empirical reasoning (observable, evidence-based thinking). The Perception Dimension (horizontal axis) contrasts Metaphorical reasoning (symbolic, figurative thinking) with Analogical reasoning (structural comparison-based reasoning). At the center, the Inference Plane consists of four key components, Representations, Assumptions, Resemblances, and Appearances, which shape reasoning processes by influencing how individuals interpret and structure knowledge. The model conceptualizes reasoning styles as distinct but interconnected, allowing any individual reasoning process to be mapped within this multi-dimensional cognitive framework. This structured approach provides insight into how people process information, make inferences, and construct logical arguments. This model conceptualizes reasoning styles as positions within a three-dimensional inference space, defined by three orthogonal axes. Each axis represents a fundamental dimension of reasoning, ranging between two poles that are distinct yet complementary. Together, these dimensions form a "general structure and inference plane" in which any particular style of reasoning can be situated.

The emergence of eight distinct reasoning styles in the scale was not an ad hoc or a posteriori decision but rather a theoretically anticipated outcome derived from the underlying model. The framework is built on three primary, dichotomous dimensions, Disposition (Empirical ↔ Hypothetical), Perception (Metaphorical ↔ Analogical), and Organization (Inductive ↔ Deductive), which, when combined, yield $2 \times 2 \times 2$ (i.e., eight) unique reasoning profiles. While the introduction might suggest an expectation of either three broad dimensions or a count of six by considering the poles, the model inherently predicts eight distinct reasoning styles as the natural intersections of these dichotomies. This theoretical prediction was later confirmed by the Exploratory Factor Analysis (EFA), which validated the eight-factor structure, thereby demonstrating that the extra dimensions were anticipated as a direct consequence of the conceptual framework rather than being a retrospective naming strategy to justify the results.

The scale's theoretical approach purposely views thinking along three separate dimensions, Disposition, Perception, and Organization, to portray the complex way that people process data. With regard to the Perception dimension, two complementary but different ways of interpretation were distinguished using the polarity of Metaphorical against Analogical reasoning. Metaphorical reasoning employs symbolic, evocative imagery and abstract associations to capture complex concepts, whereas analogical reasoning is more systematic, relying on direct comparisons of structural similarities. This distinction emerged both from our theoretical review and empirical observations of differential item responses, supporting the treatment of these approaches as opposing yet complementary poles.

Regarding the Organization dimension, we recognize that although the terms inductive and deductive are usually connected with logical reasoning, in our model *Organization* denotes the fundamental structural approach by which information is combined and handled. Whereas deductive thinking structures information by applying basic principles to draw specific conclusions, inductive reasoning is considered as structuring facts by synthesizing particular observations into broader generalizations. This conception is aimed to emphasize that people order and sequence information, whether from particulars to general concepts or vice versa, constitutes a key feature of their reasoning style, not to reinterpret accepted logical processes. Although some of the terminology may seem unusual at first, it was purposefully selected to emphasize the integrated character of various cognitive processes, and we acknowledge that additional explanation and improvement of these constructs may be advantageous in next studies Although inductive and deductive reasoning are traditionally associated with formal logic, here they serve to differentiate between the ways in which information is internally ordered and processed during reasoning.

The Reasoning Style Model is structured around three core dimensions, Disposition, Perception, and Organization, each representing a continuum that shapes inferential processes. The Disposition dimension ranges from Empirical reasoning, grounded in direct observation, experimentation, and tangible evidence [25–28], to Hypothetical reasoning, oriented toward envisioning possibilities and exploring theoretical constructs or as-yet-unproven scenarios through mental models of alternative realities [29–31]. The Perception dimension contrasts Metaphorical reasoning, which employs figurative language, symbolic representation, and evocative narratives to capture complexity [32–36], with Analogical reasoning, which draws systematic parallels between known and unknown concepts based on shared characteristics or underlying patterns [37, 38]. The Organization dimension distinguishes Inductive reasoning, building broader generalizations and hypotheses from specific observations with probabilistic conclusions [39, 40], from Deductive reasoning, which starts from established premises or theoretical constructs to reach logically consistent conclusions [21, 41]. These dimensions collectively define how individuals transition between concrete and conceptual stances, interpret information through creative or structured means, and structure information either moving outward from particulars to general concepts or inward from established generalities to specific instances.

Integrating the dimensions

Viewed together, these three axes, disposition, perception, and organization, define a three-dimensional inference space. Any given reasoning style or approach can be positioned somewhere within this conceptual framework. For example, a line of thought might be highly empirical (relying on data), metaphorical (using evocative imagery), and inductive (deriving patterns from instances), or it might be more hypothetical (conceptualizing untested ideas), analogical (mapping structural similarities), and deductive (applying established principles).

By locating reasoning styles along these three dimensions, we can better understand their nature, strengths, and weaknesses. This integrated model provides a holistic perspective on the “general structure and inference plane” of thought, clarifying how different ways of knowing and inferring relate to one another.

Reasoning styles and types

When the three axes, Disposition (Empirical ↔ Hypothetical), Perception (Metaphorical ↔ Analogical), and Organization (Induction vs. Deduction), intersect, they define a set of distinct reasoning styles. These styles can be grouped into two broad conceptual planes, each reflecting how reasoning processes either ascend from particulars to generalizations (induction) or descend from general principles to specific instances (deduction).

Induction plane

Within the induction plane, reasoning styles focus on deriving broader concepts or patterns from specific examples, observations, or representations. Depending on their disposition and perception modes, inductive reasoners may approach this process differently. Hypothetical–Inductive Reasoners (Predictive) formulate generalizations and anticipate outcomes by starting from conceptual possibilities or proposed scenarios. They use hypotheses as a springboard for discovering patterns and making forecasts. Empirical–Inductive Reasoners (Sensorial) build generalizations grounded in direct sensory experience. They rely heavily on empirical evidence, letting data guide them toward overarching principles. Metaphorical–Inductive Reasoners (Classifiers) employ symbolic or figurative representations, allowing them to classify and categorize complex phenomena. Through metaphors, they reveal underlying structures that support generalization. Analogical–Inductive Reasoners (Associative) identify and connect similar features or relationships across different domains, enabling them to generalize from one system or context to another based on shared patterns.

Deduction plane

Within the deduction plane, reasoning styles apply established general principles, theories, or assumptions to deduce specific outcomes or insights. Their distinct approaches stem from the interplay of disposition and perception. Hypothetical–Deductive Reasoners (Intuitive) start from assumptions or unproven theoretical constructs and draw logical conclusions, relying on intuition guided by conceptual frameworks. Empirical–Deductive Reasoners (Perceptual) apply factual knowledge and sensory-verified information to confirm or derive conclusions from known premises, ensuring that outcomes align with observable reality. Metaphorical–Deductive Reasoners (Imaginative) use imaginative, symbolic thinking to creatively apply general concepts to novel contexts, forging new knowledge forms from established theoretical groundings. Analogical–Deductive Reasoners (Attributive) narrow down to specific conclusions by focusing on the core attributes shared among various concepts, ensuring that deductions are consistent with the essential commonalities identified.

When examining the literature, many styles regarding cognitive processes come to the fore. For example, cognitive styles refer to an individual’s habitual, prevalent, or preferred way of thinking, learning, and teaching, and also encompass how a person perceives, processes, and applies information [42–44]. Thinking style refers to an individual’s preferred way of processing information, solving problems, and making decisions; it is not a measure of ability but rather a personal preference or inclination toward a particular mode of thinking. Thinking styles influence how people approach tasks, interact with others, and adapt to different situations [45]. Decision-making styles describe an individual's habitual approach to making decisions, characterized by distinct patterns of thinking and behavior during the decision-making process, and are more closely linked to personality traits and motivational factors than to intelligence [46]. Problem-solving style, based on the provided text, refers to the combination of cognitive and behavioral activities used to define, understand, and resolve a problem, involving the processes and strategies an individual employs when facing a problem that requires resolution [47]. A learning style describes the distinctive way in which an individual organizes, processes, represents, and integrates information into their cognitive system; it also encompasses how they retrieve and express this information [48]. Finally, mind style refers to the distinctive way individuals perceive and think, expressed through language in a manner similar to speech. It involves unique stylistic techniques tied to internal perspective, such as the use of stream of consciousness, and these techniques provide the foundation for crafting unique and identifiable mind styles [49].

While reasoning is a phenomenon which is related to what is going on in individuals' mind, investigating and assessing such constructs is relatively complex. In recent years, several instruments have been developed to capture individual differences in reasoning and thinking styles. One of the most widely used is the Sternberg–Wagner Thinking Styles Inventory, which assesses 13 distinct mental self-government styles using subscales of eight items each [43, 50]. However, rational decision-making orientations tend to favor logical reasoning over belief-based reasoning within parallel and default-interventionist models [51]. More recently, the Evidence-versus-Advice (EvA) Scale decomposed epistemic preferences into four factors that predict susceptibility to misinformation [52], while the Intuitive–Analytical Cognitive Styles distinguishes between complementary cognitive processing systems across multiple dimensions [53]. Although these models offer important insights, they either emphasize a relatively narrow set of dimensions (e.g., empirical vs. hypothetical in EvA) or rely on broad dual-process dichotomies (e.g., intuitive vs. analytical), leaving other theoretically meaningful axes underexplored. The present 8-FRSS addresses this gap by integrating three orthogonal dimensions—Disposition (Empirical ↔ Hypothetical), Perception (Metaphorical ↔ Analogical), and Organization (Inductive ↔ Deductive)—to generate eight distinct reasoning profiles. By combining these axes, the 8-FRSS not only aligns with the multifaceted nature of inferential processes proposed in classical philosophical accounts but also provides more granular psychometric coverage than existing measures, ensuring that each dimension is represented by conceptually coherent item sets and empirically validated factor structures.

Despite the conceptual overlap among these styles, reasoning styles differ in a crucial way: they focus on how individuals systematically form, test, and revise inferences, drawing upon specific orientation axes, such as empirical versus hypothetical sources of information, metaphorical versus analogical forms of interpretation, and inductive versus deductive organizational approaches. While cognitive styles, thinking styles, decision-making styles, problem-solving styles, learning styles, and mind styles highlight individual tendencies, preferences, or behavioral patterns in processing and applying information, reasoning styles emphasize the inferential frameworks themselves. By clarifying how people gather and integrate evidence, propose hypotheses, and arrive at conclusions, reasoning styles provide deeper insight into why different individuals might produce varied logical outcomes or judgments, even when they share similar cognitive abilities or personality traits. This focus on inferential frameworks renders reasoning styles important because they illuminate the structural underpinnings of thought processes that cut across disciplines, contexts, and content areas. Understanding these styles can guide educators in tailoring instruction that respects diverse reasoning orientations, help researchers design more targeted interventions for improving logical and analytical skills, and enable practitioners to anticipate and resolve conflicts arising from incompatible reasoning approaches. Consequently, while the other cognitive and behavioral styles underscore how people habitually think, learn, or decide, reasoning styles reveal how and why a person's line of reasoning unfolds, and thus hold critical relevance for both theoretical understanding and practical application in fields ranging from educational psychology to decision science.

The reasoning styles model proposed in this paper provides a comprehensive map for understanding diverse reasoning styles. By situating thinking patterns along the axes of disposition, perception, and organization, we can more effectively analyze cognitive approaches used in education, scientific inquiry, and problem-solving. The resulting classification illuminates how distinct reasoning styles evolve from varying combinations of empirical or hypothetical stances, metaphorical or analogical interpretations, and inductive or deductive organizational structures.

Methodology

This study employed a sequential, mixed-methods design, predominantly quantitative in nature, to develop the 8-FRSS and determine its psychometric properties.

The research proceeded in several phases: (a) item generation based on the Reasoning Style Model, (b) scale construction, (c) data collection from two independent samples, (d) exploratory and confirmatory factor analyses, and (e) reliability and validity assessments.

Participants and sampling

The research was carried out by drawing from undergraduate students in a range of academic departments to ensure disciplinary diversity. Three separate samples were used to bolster the robustness of the findings and reduce the risk of overfitting. Participants for the EFA were recruited via convenience sampling from five distinct academic departments (Education, Psychology, Mathematics, Physics, and Sociology) at Iğdır University, Ağrı İbrahim Çeçen University and Ondokuz Mayıs University. Data collection took place in supervised classroom sessions, where trained research assistants introduced the study, obtained informed consent, and monitored questionnaire completion to minimize missing data. Respondents were between 18 and 25 years old (M = 23, SD = 1.8); the largest age groups were 20-year-olds (25.0%, $n = 110$) and 19-year-olds (2.0%, $n = 88$), with smaller proportions of 18-year-olds (12.5%, $n = 55$), 21-year-olds (2.0%, $n = 88$), 22-year-olds (12.0%, $n = 53$), and those aged ≥ 23 years (1.5%, $n = 47$). The sample was 65.1% female ($n = 287$) and 34.9% male ($n = 154$).

For Confirmatory Factor Analysis (CFA), we recruited a second cohort of undergraduates using the same convenience-sampling procedures but from different course sections to avoid overlap with Sample 1. Administration was again classroom-based and supervised. Ages ranged from 18 to 26 years (M = 26, SD = 1.9). The modal age was 20 (28.2%, $n = 89$), followed by 19 (22.2%, $n = 70$), 21 (18.0%, $n = 57$), 22 (11.7%, $n = 37$), 18 (1.4%, $n = 33$), and ≥ 23 (9.5%, $n = 30$). The gender distribution was 68.0% female ($n = 215$) and 32.0% male ($n = 101$).

To assess generalizability, we assembled a third, independent sample ($N = 604$) via online convenience sampling with snowball recruitment through university mailing lists, social-media groups, and professional networks. After excluding one incomplete response, the final $N = 603$ spanned ages 14 to 63 years (M = 21.4, SD = 4.3). A majority were 18–24 years old (7.6%, $n = 426$)—most frequently 20 (14.9%, $n = 90$) and 21 (14.6%, $n = 88$)—with 7.8% under 18 ($n = 47$) and 5.3% over 30 ($n = 32$). Females comprised 77.5% ($n = 468$) and males 22.5% ($n = 136$). This broader age and gender mix confirms that the 8-FRSS factor structure holds beyond the undergraduate context.

In both cases, participants were selected using convenience sampling, yet efforts were made to include students from various departments, thereby increasing the representativeness and the external validity of the results.

Prior to data collection, the study received approval from the institution's research ethics committee. The objectives, procedures, and voluntary nature of the study were explained, and all participants provided informed consent. Confidentiality and anonymity were guaranteed by assigning numeric codes to each participant.

Instruments: convergent validity with the Sternberg–Wagner thinking styles inventory

The Sternberg-Wagner Thinking Styles Inventory, developed by Sternberg and Wagner [43], was designed based on the predictions of the Theory of Mental Self-Government. The original inventory consists of 13 subtests, each containing eight items, totaling 104 items, and uses a 7-point Likert-type scale for self-reporting. In Turkey, the inventory was first adapted into Turkish by Buluş [50], during which the number of items was reduced to 65. In the adaptation study, item-total correlations were found to range between 0.31 and 0.84, while the Cronbach's alpha coefficients for the subtests ranged from 0.66 (for the anarchic style) to 0.93 (for the monarchic style). The factor structure of the scale was examined using the principal components method with varimax rotation, revealing five main factors with eigenvalues of 3.1, 1.9, 1.4, 1.2, and 1.1, accounting for a total of 68.3% of the variance. The results related to internal consistency reliability and construct validity were found to be consistent with the findings reported by Sternberg and Wagner [43], Sternberg [43], and Zhang and Sachs [54].

To evaluate criterion-related convergent validity, an independent sample of 604 adults was recruited via online survey panels. Participants completed both the 8-Factor Reasoning Styles Scale (8-FRSS) and the Sternberg–Wagner Thinking Styles Inventory [50], which measures 13 thinking styles grounded in the Theory of Mental Self-Government. Each subscale of the Sternberg–Wagner inventory comprises eight items rated on a 7-point Likert scale.

We developed the 8-FRSS [See Additional file 1] from an initial pool of 40 theory-driven items, allocating five items to each of the eight reasoning styles. Respondents indicate their agreement with each statement using a 5-point Likert-type scale (1 = "Strongly Disagree," 2 = "Disagree," 3 = "Neutral," 4 = "Agree," 5 = "Strongly Agree"). To reduce potential order effects, all items were randomized within the questionnaire, and each was worded positively so that higher scores uniformly reflect greater endorsement of the targeted reasoning style.

Scale construction and item development

Beginning with a thorough examination of the theoretical literature on reasoning, the development of the items for the 8-FRSS was anchored in a rigorous, multi-stage process. Inspired by foundational writings by academics like

Hacking [2] and Crombie [3], we investigated the several historical and modern conceptual approaches for reasoning. This study produced a thorough theoretical model encompassing three main dimensions of reasoning: Disposition (from Empirical to Hypothetical), Perception (from Metaphorical to Analogical), and Organization (covering Inductive rather than Deductive reasoning). Every one of these aspects was seen to contribute specifically to the general reasoning process, and taken together they generate eight different approaches. Building on this theoretical basis, the next phase was creating a first pool of objects that would operationalize these abstract qualities into quantifiable markers. Items were painstakingly created to reflect the disparity between a dependence on tangible, visible evidence (Empirical) and the capacity for abstract, theoretical reasoning (Hypothetical), in the Disposition dimension. Likewise, for the Perception dimension, objects were designed to distinguish between analogical reasoning, which stresses methodical, structural comparisons between ideas, and metaphorical thinking, which uses figurative language and symbolic representation. Items were made to evaluate both deductive processes, where known premises are used to infer conclusions, and inductive processes, in which generalizations are drawn from particular observations, in addressing the Organization dimension.

After the first draft, the item pool was carefully content validated by expert review. Every item faithfully mirrored its intended construct as a panel of experts in educational psychology and measurement theory assessed the items for clarity, theoretical alignment, and content validity. Their comments led to improvements in the items' conceptual accuracy as well as their readability. A pilot test with a small sample of undergraduate students was carried out to guarantee even more that the things worked as expected. This pilot phase let us evaluate the items' comprehensibility, the response format's practicality, and compile the first psychometric data on them. This stage's insights resulted in further changes including rewording vague objects and deleting those that performed poorly.

In the end, this iterative procedure encompassing theoretical formulation, expert review, and pilot testing produced a set of items both theoretically grounded and empirically strong (Additional file 1). The thorough construction of these objects underpins the scale's capacity to consistently and correctly evaluate the multifarious character of human reasoning across the eight defined styles (Table 2).

Table 2 Scale subdimensions and item numbers

Reasoning Style	Item Numbers
Empirical–Deductive	1–4
Metaphorical–Deductive	5–7
Hypothetical–Deductive	8–10
Metaphorical–Inductive	11–13
Analogical–Deductive	14–16
Analogical–Inductive	17–20
Hypothetical–Inductive	21–23
Empirical–Inductive	24–26

Data collection procedures

Once the scale items were finalized, the instrument was administered to the first sample (EFA sample). Students completed the questionnaire in classroom settings under the supervision of trained research assistants. Any incomplete or illegible questionnaires were excluded from analysis. First, the two cases (Case 1 and Case 5) were removed from the dataset due to the identified anomaly, and 12 duplicate cases were removed from the dataset. The final EFA sample thus comprised 441 valid responses.

For the CFA phase, the revised scale, incorporating initial adjustments based on EFA insights, was administered to a separate group of 316 undergraduate students from the same institution but different class sessions and departments. This sampling approach minimized the risk of overlap between the two groups and strengthened the generalizability of the confirmation results.

Data analysis

All data preprocessing, descriptive statistics, and reliability analyses (Cronbach's α and McDonald's ω) were carried out in IBM SPSS Statistics. EFA (including parallel analysis) and CFA (with computation of CFI, TLI, RMSEA, SRMR, and related fit indices) were conducted using JASP. All confirmatory factor analyses were conducted in JASP (version 0.16.4) using the Diagonally Weighted Least Squares (DWLS) estimator on a polychoric correlation matrix, which is specifically designed for ordered-categorical (polytomous) data such as our 5-point Likert items. This estimator appropriately models the ordinal nature of the response scale and yields robust parameter estimates and fit indices.

- Preliminary Screening and Assumption Checks:
- Prior to conducting the main analyses, data were screened for missing values, duplicate entries, and outliers. Cases exhibiting anomalies or excessive missing responses were excluded. The assumptions of normality and linearity were assessed through skewness and kurtosis indices as well as scatterplots, ensuring the appropriateness of the data for factor analyses.
- EFA:
- An EFA (Fig. 2) was conducted on the first sample ($n = 441$) to identify the underlying factor structure. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was excellent (0.932), and

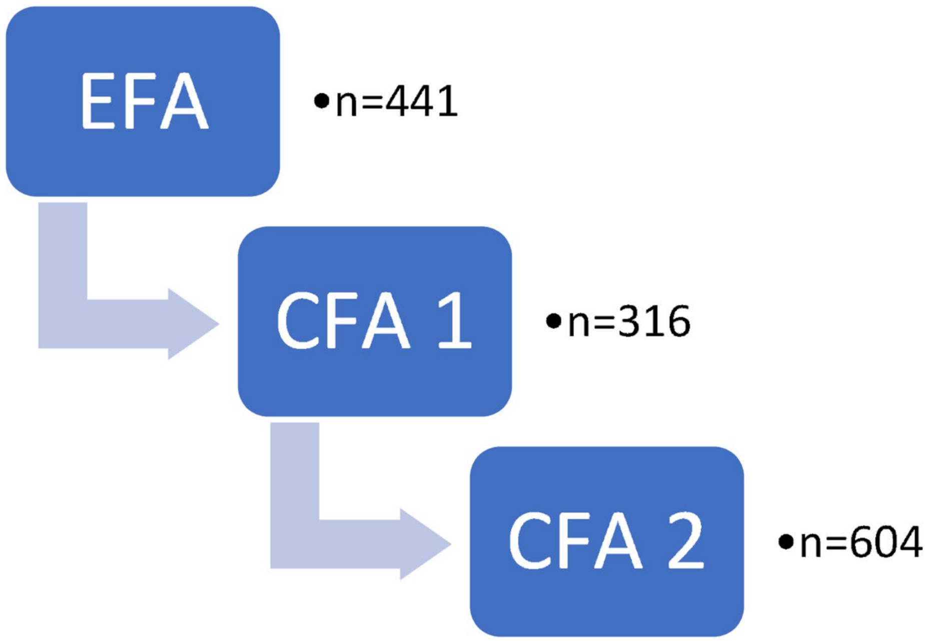

Fig. 2 The general research processs

Bartlett's test of sphericity was highly significant ($p < .001$), confirming the suitability of the data for factor analysis. Factors with eigenvalues greater than 1 were initially retained, complemented by the visual inspection of the scree plot, which further supported the retention of eight factors. Items demonstrating high cross-loadings or weak loadings were removed. The final EFA structure aligned with the theoretically proposed eight-factor model (Empirical-Deductive, Metaphorical-Deductive, Hypothetical-Deductive, Metaphorical-Inductive, Analogical-Deductive, Analogical-Inductive, Hypothetical-Inductive, Empirical-Inductive), accounting for 58.2% of the total variance.

- CFA:
- A CFA (Fig. 2) was subsequently performed on a second independent sample ($n = 316$) to validate the eight-factor structure identified in the EFA. Model fit was assessed using multiple indices: Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Non-Normed Fit Index (NNFI), Root Mean Square Error of Approximation (RMSEA), Goodness-of-Fit Index (GFI), Incremental Fit Index (IFI), Root Mean Square Residual (RMR), and Standardized Root Mean Square Residual (SRMR). Good model fit was defined by CFI, TLI, and IFI values ≥ 0.90, RMSEA ≤ 0.08, and SRMR ≤ 0.05. Iterative item removal based on modification indices was undertaken to optimize model fit without compromising theoretical integrity.
- Cross-Validation with a Third Sample:
- To assess the generalizability and external validity of the model, a third CFA was conducted on a broader community sample ($n = 604$) (Fig. 2).
- Concurrent Validity Assessment:
- To evaluate criterion-related convergent validity (specifically concurrent validity), correlations between the 8-FRSS and the Sternberg–Wagner Thinking Styles Inventory [50] were examined. All cross-scale correlations were positive and statistically significant ($p < .01$), supporting the concurrent validity of the 8-FRSS. Strongest associations were observed between analogical reasoning styles and task-oriented thinking styles ($r \approx .50–0.61$), whereas moderate to lower correlations ($r \approx .30–0.48$ and $r \approx .15–0.29$) further affirmed the scale's ability to map theoretically consistent cognitive constructs.
- Reliability and Internal Consistency:
- Internal consistency of the 8-FRSS was evaluated using Cronbach's alpha (α) and McDonald's omega (ω). Overall, the scale demonstrated high reliability, with α and ω values exceeding 0.70 for most factors. Factors with reliability estimates below 0.60 were subjected to additional scrutiny for future refinement. Inter-factor correlations were positive and coherent with theoretical expectations, providing additional support for the internal structure and construct validity of the instrument.

Ethical considerations

All participants were informed about the study's objectives, the voluntary nature of participation, and the confidentiality of the data. No identifiable personal information was collected, and numeric codes were used to manage the responses. The study adhered to ethical standards outlined by the institutional review board, ensuring that participants' rights and well-being were safeguarded throughout the research process. To enhance the clarity and fluency of the manuscript, we utilized GPT-4 for language editing.

Results

Content and face validity

Content and face validity were rigorously established to ensure the scale's items were theoretically sound and interpretable by respondents, aligning with the intended constructs of reasoning styles.

Content validity Content validity was achieved through a comprehensive review by a panel of five experts in measurement theory, educational psychology, and cognitive science. The panel evaluated the initial pool of 40 items for theoretical alignment, clarity, and uniqueness, ensuring each item distinctly contributed to its intended reasoning dimension (e.g., Empirical-Deductive, Hypothetical-Inductive). For example, items designed to measure Empirical-Deductive reasoning were scrutinized to confirm they emphasized reliance on observable evidence without overlapping with Hypothetical-Deductive items, which focus on theoretical premises. The experts used a structured evaluation rubric, rating each item on a 4-point scale (1 = not relevant, 4 = highly relevant) for relevance to the construct and clarity of wording. Items scoring below 3 were revised or removed. Approximately 10 items were rephrased for precision (e.g., an item initially worded as "I solve problems by reasoning from evidence" was revised to "I rely on observable data to draw logical conclusions" to avoid ambiguity). Three items were eliminated due to redundancy, such as items measuring Analogical-Inductive reasoning that were too similar in phrasing. The panel also provided qualitative feedback, suggesting cultural and contextual adjustments to ensure the items were appropriate for the target population (undergraduate students). This iterative process ensured that the scale comprehensively covered the theoretical framework while maintaining item distinctiveness.

Face validity Face validity was established through a pilot test with a diverse sample of 50 undergraduate students, representing the target population in terms of age, academic background, and cultural diversity. Participants completed a preliminary version of the scale and provided structured feedback through open-ended questions and semi-structured interviews. They were asked whether the items were clear, relevant to their reasoning experiences, and easy to interpret. For instance, several students noted that items in the Metaphorical-Inductive dimension, such as "I use metaphors to generate ideas," were initially confusing because the term "metaphors" was not immediately intuitive. Based on this feedback, these items were rephrased (e.g., to "I use creative comparisons to form new ideas") to enhance accessibility. Additionally, students highlighted that some items in the Hypothetical-Deductive dimension used technical language (e.g., "I formulate hypotheses based on theory"), which was simplified to "I make predictions based on ideas" to improve comprehension without altering the construct's essence. The pilot test also identified minor formatting issues, such as inconsistent response scales, which were standardized to a 5-point Likert scale for consistency. Interviews revealed that students found the revised items intuitive and reflective of their reasoning processes, confirming the scale's face validity. This combination of qualitative feedback and iterative revisions ensured that the scale was not only statistically robust but also practically meaningful to respondents.

Concurrent validity The findings offer robust evidence for the concurrent validity of the Reasoning Styles Scale. Specifically, by correlating the newly developed scale with Sternberg's established Thinking Styles framework, and conducting these assessments simultaneously, the study effectively evaluates the extent to which both instruments measure related cognitive constructs.nThe correlation matrix reveals a consistent pattern wherein all cross-scale coefficients are positive and statistically significant ($p < .01$). This indicates that greater endorsement of a given reasoning style is systematically associated with stronger preferences for corresponding thinking styles, as theoretically anticipated. The highest correlations (approximately $r = .50–0.61$) are observed between analogical reasoning styles (both deductive and inductive) and the task-oriented legislative, executive, and judicial thinking styles ($r = .51–0.65$), reflecting strong conceptual convergence. These findings suggest that the Reasoning Styles Scale captures core cognitive processes aligned with structured, goal-driven cognitive functioning. Moderate correlations ($r \approx .30–0.48$), primarily involving hierarchical, monarchical, oligarchic, and anarchic thinking styles, further support concurrent validity while reflecting the increasing complexity and multiplicity of goals associated with these styles. Meanwhile, lower but still statistically significant correlations ($r \approx .15–0.29$) with broader cognitive profiles such as the global and conservative styles, as well as the hypothetical-deductive reasoning mode, suggest that while some constructs overlap only partially, the Reasoning Styles Scale nevertheless captures meaningful dimensions of cognitive functioning.

Overall, the observed graded correlation pattern—stronger where theoretical overlap is highest and attenuated

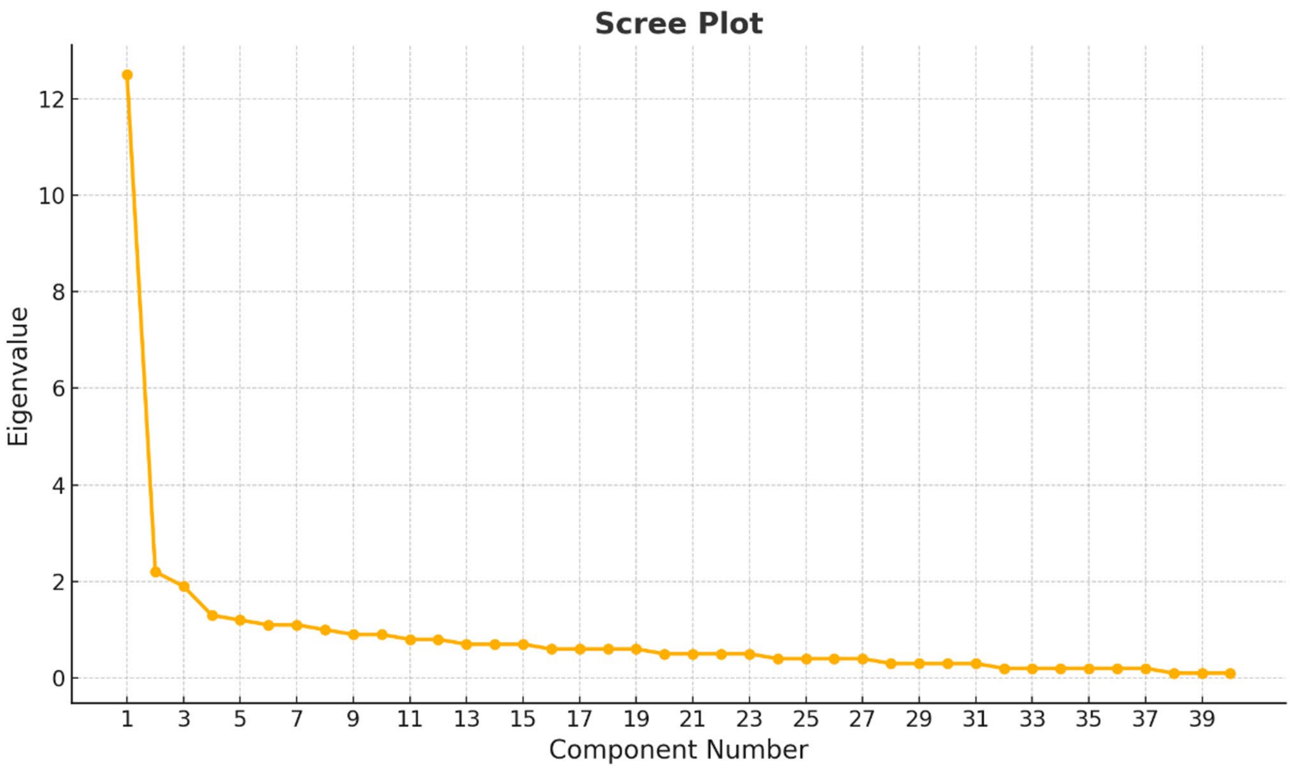

Fig. 3 Scree plot of EFA

where constructs naturally diverge—provides compelling support for the concurrent validity of the Reasoning Styles Scale. These results affirm that the instrument measures cognitive operations in ways that are theoretically coherent and empirically consistent with an established framework.

EFA

EFA was conducted to uncover the underlying structure of the scale. To ensure data integrity, 12 duplicate cases were identified and removed from the dataset, as they could artificially inflate correlations. Additionally, two anomalous cases (Case 1 and Case 5) were excluded due to irregular response patterns that could distort the factor structure. An EFA was employed as the extraction method to assess construct validity, determining whether the items measured the intended theoretical constructs.

The suitability of the dataset for factor analysis was confirmed through statistical tests. Bartlett's test of sphericity yielded a highly significant result (χ^2 = 7014.336, df = 703, $p < .001$), indicating sufficient inter-variable correlations for factor extraction. The KMO measure of sampling adequacy was 0.932, well above the 0.60 threshold, signifying excellent suitability for identifying distinct factors.

The scree plot obtained from the EFA visually supports the retention of an eight-factor structure for the 8-FRSS. As shown in Fig. 3, the plot reveals a distinct "elbow" after the first few components, with a sharp decline in eigenvalues between Components 1 and 3, followed by a gradual leveling off from approximately the 7th or 8th component onward.

Table 3 Total variance explained

Component	Extraction Sums of Squared Loadings	% of Variance	Cumulative %
1	12.454	32.773	32.773
2	2.048	5.390	38.162
3	1.886	4.963	43.125
4	1.326	3.490	46.615
5	1.234	3.248	49.863
6	1.100	2.895	52.758
7	1.087	2.860	55.618
8	0.988	2.601	58.219

The analysis identified seven components with eigenvalues greater than 1, collectively explaining 58.2% of the total variance in the dataset. This substantial proportion of variance indicates that the retained factors effectively summarize the data while reducing complexity. Items 11 and 13 were removed due to cross-loadings on multiple factors, which compromised their assignment to a single construct (Table 3.1).

The Pattern Matrix (Table 4) presents factor loadings after EFA, an oblique method allowing correlated factors.

Table 4 Factor loadings (Pattern Matrix)

Item	Empirical -Deductive	Metaphorical -Deductive	Hypothetical -Deductive	Metaphorical -Inductive	Analogical -Deductive	Analogical -Inductive	Hypothetical -Inductive	Empirical -Inductive
1							0.800	
2							0.780	
3							0.730	
4						0.463		
5								0.642
7								0.374
8								0.704
9						0.578		
10						0.526		
14				0.684				
15				0.740				
17						0.510		
21	0.504							
23			0.761					
24			0.865					
25			0.800					
26	0.413							
27	0.504							
30	0.522							
32		0.660						
34		0.665						
35		0.496						
37					0.491			
38					0.562			
39					0.678			

Table 5 Fit indices and metric values for the second sample

Fit Index/Metric	Value
CFI	0.918
TLI	0.901
NNFI	0.901
NFI	0.841
PNFI	0.701
RFI	0.809
IFI	0.919
RNI	0.918
RMSEA	0.052
RMSEA 90% CI Lower Bound	0.045
RMSEA 90% CI Upper Bound	0.059
RMSEA p-value	0.291
SRMR	0.047
Hoelter's Critical N (α = 0.05)	195.200
Hoelter's Critical N (α = 0.01)	206.265
Goodness of Fit Index (GFI)	0.975
McDonald Fit Index (MFI)	0.690
Expected Cross Validation Index (ECVI)	2.269

Table 6 Fit indices and metric values for the third sample

Metric	Value
CFI	0.897
TLI	0.877
NNFI	0.877
NFI	0.855
PNFI	0.713
RFI	0.826
IFI	0.898
RNI	0.897
Log-likelihood	-19403.644
Number of free parameters	106.000
Akaike Information Criterion (AIC)	39019.288
Bayesian Information Criterion (BIC)	39486.067
Sample-size adjusted Bayesian Information Criterion (SSABIC)	39149.543
Root Mean Square Error of Approximation (RMSEA)	0.057
RMSEA 90% CI lower bound	0.053
RMSEA 90% CI upper bound	0.062
RMSEA p-value	0.004
Standardized Root Mean Square Residual (SRMR)	0.048
Hoelter's Critical N (α = 0.05)	232.062
Hoelter's Critical N (α = 0.01)	245.226
Goodness of Fit Index (GFI)	0.980
McDonald Fit Index (MFI)	0.639
Expected Cross Validation Index (ECVI)	1.694

The results confirmed that most items aligned with specific reasoning styles, such as Empirical-Deductive or Hypothetical-Inductive, supporting the scale's theoretical framework. Several items were removed during confirmatory analysis based on modification indices and expert validation to enhance model fit.

Sole reliance on the Kaiser "eigenvalue > 1" criterion can systematically underestimate the true number of factors, particularly in scales with a strong theoretical basis and moderately complex item intercorrelations. As Costello and Osborne [55] demonstrate, the eigenvalue-greater-than-one rule often truncates factor retention by neglecting weaker but theoretically meaningful dimensions, leading researchers to overlook low-variance factors that nonetheless capture important constructs. In contrast, supplementing this rule with scree-plot inspection and parallel analysis helps reveal the "elbow" point and compare observed eigenvalues against those from random data, ensuring that subtler factors are not dismissed solely because their eigenvalues fall just below unity. Although only seven factors exceeded the Kaiser threshold, both the scree plot and parallel analysis supported an eight-factor solution in alignment with our three-axis theoretical model, thereby validating the retention of the eighth factor despite its eigenvalue of 0.988 [55].

CFA

The CFA model exhibits a strong overall fit based on multiple indices (Table 5). The Comparative Fit Index (CFI = 0.918), Tucker-Lewis Index (TLI = 0.901), Bentler-Bonett Non-normed Fit Index (NNFI = 0.901), Bollen's Incremental Fit Index (IFI = 0.919), and Relative Noncentrality Index (RNI = 0.918) all exceed the commonly accepted threshold of 0.90, indicating that the model fits the observed covariance structure reasonably well compared to a null model. However, the Bentler-Bonett Normed Fit Index (NFI = 0.841), Parsimony Normed Fit Index (PNFI = 0.701), and Bollen's Relative Fit Index (RFI = 0.809) fall below the 0.90 mark, which points to potential issues regarding model complexity or misspecification. Additional metrics (Table 6) include RMSEA = 0.052 (90% CI: 0.045–0.059), SRMR = 0.047, and GFI = 0.975, further supporting the model's fit. Items 6, 12, 18, 19, 20, 22, 28, 29, 31, 33, 36, and 40 were removed based on modification indices and expert review to improve fit, though item 19 was retained to ensure at least three items per factor. Although most fit statistics met or exceeded recommended benchmarks, the NFI (0.841) and PNFI (0.701) remain below the ideal 0.90 cutoff. This may partly reflect the limited number of items (two to three) in some factors, as well as possible method variance. Future work should address these issues by exploring more flexible modeling approaches and by refining items with suboptimal loadings.

Beyond fit indices, we have closely examined how each factor corresponds to its theoretical dimension. The Empirical–Deductive factor (e.g., "I rely on observable data to draw logical conclusions") reflects evidence-based rule application, while Metaphorical–Deductive captures creative symbolic framing of general principles. Hypothetical–Deductive emphasizes intuition-driven

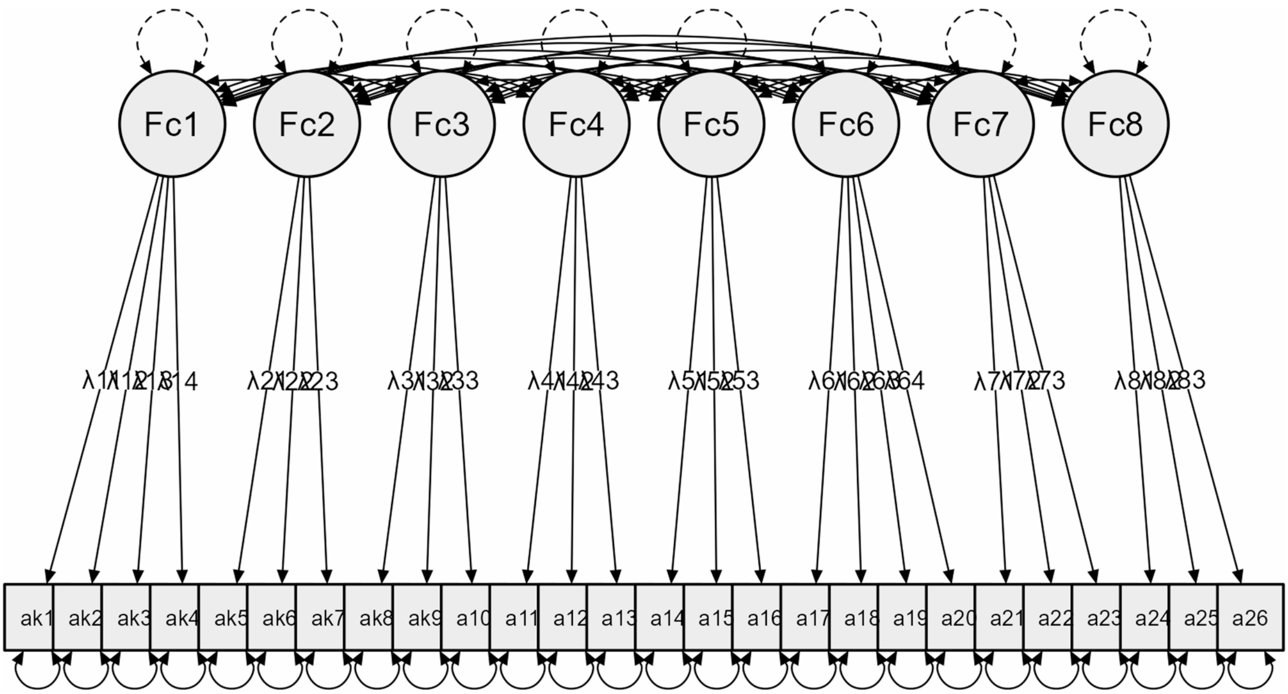

Fig. 4 The structural representation of the 8-FRSS

inference from assumptions. On the inductive side, Metaphorical–Inductive involves generating generalizations through figurative comparisons; here, Item 19 ('When explaining a phenomenon, I use a similar phenomenon as an example') was re-included and demonstrates a strong loading of 0.712, ensuring that this dimension retains sufficient breadth. Analogical–Inductive and Empirical–Inductive factors represent pattern generalization from structural mappings and sensory data, respectively. Together, these descriptions confirm that each factor's empirical loadings align with the intended inferential constructs.

To further evaluate the generalizability of the eight-factor structure, we conducted a CFA on the independent community sample ($N = 604$). The replicated model yielded fit indices that, while slightly lower than the student samples, still approached acceptable thresholds: Comparative Fit Index (CFI) = 0.897, Tucker–Lewis Index (TLI) = 0.877, Bentler–Bonett Non-normed Fit Index (NNFI) = 0.877, Bentler–Bonett Normed Fit Index (NFI) = 0.855, Parsimony Normed Fit Index (PNFI) = 0.713, Bollen's Relative Fit Index (RFI) = 0.826, Bollen's Incremental Fit Index (IFI) = 0.898, and Relative Noncentrality Index (RNI) = 0.897. Information criteria also indicated a stable solution (AIC = 39019.29; BIC = 39486.07; ECVI = 1.694) (Table 6). Additional indices showed RMSEA = 0.057 (90% CI = 0.053–0.062; $p = .004$), SRMR = 0.048, Hoelter's critical $N = 232$ at $\alpha = 0.05$ and 245 at $\alpha = 0.01$, and GFI = 0.98. Although some incremental fit indices fell just below 0.90, the pattern of loadings and residuals remained consistent with the original model, confirming the robustness of the eight-factor solution across a broader population [56].

Table 7 McDonald's ω and cronbach's α coefficients for each of the eight reasoning style factors, as well as the overall scale

Factor	Coefficient ω	Coefficient α
Empirical-Deductive	0.727	0.715
Metaphorical-Deductive	0.728	0.723
Hypothetical-Deductive	0.482	0.595
Metaphorical-Inductive	0.680	0.682
Analogical-Deductive	0.754	0.752
Analogical-Inductive	0.716	0.714
Hypothetical-Inductive	0.769	0.761
Empirical-Inductive	0.697	0.689
Total	**0.926**	**0.909**

This diagram in Fig. 4 illustrates the structural representation of the 8-FRSS, a psychometrically validated instrument developed to assess reasoning styles across a three-dimensional theoretical model: Disposition (Empirical–Hypothetical), Perception (Metaphorical–Analogical), and Organization (Inductive–Deductive).

Reliability and inter-factor correlations

Table 7 presents both McDonald's ω and Cronbach's α coefficients for each of the eight reasoning style factors, as well as the overall scale. Six subscales—Factors 1 (ω = 0.727, α = 0.715), 2 (ω = 0.728, α = 0.723), 4 (ω = 0.680, α = 0.682), 5 (ω = 0.754, α = 0.752), 6 (ω = 0.716, α = 0.714), and 7 (ω = 0.769, α = 0.761)—demonstrate acceptable internal consistency (≥ 0.70). Factors 3 (ω = 0.482, α = 0.595) and 8 (ω = 0.697, α = 0.689) fall below the conventional reliability threshold, indicating these subscales would benefit from further item refinement. The total scale exhibits excellent reliability (ω = 0.926; α = 0.909), reflecting high overall consistency when the full instrument is treated as a single composite measure.

Convergent validity, which ensures items within a factor measure the same concept, was assessed using CR and AVE. CR values (Table 8) ranged from 0.632 to 0.829, all above 0.60, supporting convergent validity. AVE values, which measure the variance captured by the construct relative to measurement error, ranged from 0.331 to 0.623. Although some AVE values were below the ideal 0.50, the strong CR values suggest acceptable validity, as high CR can compensate for slightly lower AVE in practice [57, 58].

All inter-factor correlations were positive and reached statistical significance ($p < .01$), demonstrating that while each of the eight reasoning styles is unique, they nonetheless share relationships. The highest association occurred between Empirical-Deductive and Analogical-Deductive reasoning ($r = .634$), implying that those who favor rule-based logic also tend to engage in structural comparisons. In contrast, Hypothetical-Deductive reasoning correlated more modestly with the other styles (ranging from 0.207 to 0.324), underscoring its foundation in theoretical rather than empirical or analogical processes (see Table 9).

Table 8 AVE and CR results

Factor	Indicators (*n*)	AVE	CR
Empirical-Deductive	4	0.425	0.745
Metaphorical-Deductive	3	0.451	0.711
Hypothetical-Deductive	3	0.623	0.829
Metaphorical-Inductive	3	0.447	0.707
Analogical-Deductive	3	0.459	0.718
Analogical-Inductive	4	0.331	0.662
Hypothetical-Inductive	3	0.488	0.740
Empirical-Inductive	3	0.366	0.632

Notes: AVE = Average Variance Extracted; CR = Composite Reliability

Discussion

This study developed and validated the 8-FRSS, grounded in the Reasoning Style Model. The scale, designed to differentiate reasoning along three dimensions—Disposition (Empirical ↔ Hypothetical), Perception (Metaphorical ↔ Analogical), and Organization (Inductive ↔ Deductive)—was developed through a sequential mixed-methods approach involving extensive item generation, expert review, pilot testing, and rigorous statistical analyses, including both EFA and CFA. The EFA, conducted on the first sample ($n = 441$), confirmed an eight-factor structure explaining 58.2% of the total variance, consistent with the theoretically proposed model. Subsequently, a CFA was performed on an independent second sample ($n = 316$) to validate this structure, yielding robust model fit indices (CFI = 0.918, TLI = 0.901, RMSEA = 0.052), thus supporting the scale's structural validity. To further strengthen the generalizability and stability of the model, a third CFA was conducted on a larger and independent community sample ($n = 604$). Although the fit indices from the third CFA were slightly lower than those observed in the student samples (CFI = 0.897, TLI = 0.877, RMSEA = 0.057), they remained within acceptable thresholds and confirmed the eight-factor solution across a broader and more heterogeneous population. This additional validation step provided strong evidence for the robustness of the 8-FRSS's factorial structure across different contexts, enhancing the external validity of the instrument and supporting its applicability in both academic and non-academic settings. The survival of all eight theorized factors in both EFA and CFA confirms that reasoning cannot be reduced to the more familiar binary of *inductive–deductive* logic or to global *analytic-intuitive* dichotomies [29, 59]. Instead, our findings provided clear empirical evidence that individuals employed diverse yet interconnected reasoning styles when acquiring, organizing, and interpreting information, underscoring the multifaceted nature of cognitive processes. The finding aligned with the previous cognitive research [52] which demonstrated that individuals' preferences for evidence-based or advice-based reasoning are multidimensional, and not easily reducible to a single cognitive dimension.

Table 9 Correlations among dimensions

Dimension	1	2	3	4	5	6	7	8
1. Empirical–Deductive	1.000	0.508	0.324	0.454	0.634	0.592	0.553	0.585
2. Metaphorical–Deductive		1.000	0.257	0.491	0.523	0.465	0.392	0.357
3. Hypothetical–Deductive			1.000	0.249	0.280	0.244	0.207	0.208
4. Metaphorical–Inductive				1.000	0.464	0.457	0.422	0.388
5. Analogical–Deductive					1.000	0.516	0.460	0.447
6. Analogical–Inductive						1.000	0.481	0.523
7. Hypothetical–Inductive							1.000	0.512
8. Empirical–Inductive								1.000

Note. All correlations are significant at $p < .01$

Furthermore, evidence that reasoning dispositions are multi-dimensional has grown rapidly over the last two years. EvA scale [52], for instance, decomposed epistemic preferences into four separable tendencies that jointly predict susceptibility to misinformation. Likewise, the Intuitive-Analytical Cognitive Styles inventory [60] partitions thinking into complementary systems rather than a single continuum. Now, in our study, 8-FRSS advanced this trajectory by demonstrating that at least three orthogonal axes are needed to recover the latent geometry of reasoning: epistemic source (empirical–hypothetical), representational lens (metaphorical–analogical), and inferential direction (induction–deduction). To improve model fit and enhance construct representation, we propose three follow-up strategies:

a. Bifactor/ESEM modeling to allow for both general reasoning variance and specific style factors,
b. Targeted item revision—adding or rewording items in subscales with low AVE or weak loadings,
c. Cross-validation of the revised structure in more diverse samples (e.g., community populations) to ensure robustness across contexts.

Although the eight reasoning methods are fundamentally different, our results show that positive inter-factor correlations imply that people might use several techniques depending on situation or personal inclination, which aligns with Ian Hacking's theory of *styles of reasoning*, which posits that reasoning frameworks are historically contingent yet overlapping systems that shape how people interpret evidence and truth [8]. Under direction by both statistical indications (such as cross-loadings and weak factor loadings) and expert judgment, the iterative item revision process produced a scale with typically high internal consistency, as shown by appropriate Cronbach's Alpha and McDonald's Omega values across most factors. Two subscales, however, showed rather poor dependability, pointing up areas that might call for more improvement. This pattern matched with the findings from the scale development study of Drummond and Fischhoff [61], in which multifactorial models often required refinement, particularly when measuring cognitive tendencies across diverse contexts. In multifactorial scales, actually, the need for model adjustments is common. Another study [62] have demonstrated that even well-constructed scales often require refinement when applied across varied demographic or contextual settings. Theoretically, our approach resonates with the cognitive style framework proposed by Kozhevnikov [63], suggesting that reasoning operates through various regulatory heuristics at perceptual, cognitive, and metacognitive levels. Moreover, the notion that reasoning styles are *culturally* and *contextually* mediated is consistent with socio-cultural theories [64], which emphasize the *socially constructed* nature of reasoning processes.

Conceptually, the 8-FRSS bridges three cornerstones in the literature that have seldom been integrated. First, it supported Hacking's [4] and Hacking's [2] historical-philosophical account of *styles of reasoning*—relatively self-contained repertoires that determine what "counts" as a fact or a good argument in a given community. Like Hacking's styles, the present factors are *equiprimordial* (i.e., none is foundational to the others) yet inter-penetrating, as reflected in the moderate positive inter-correlations we observed. Second, by locating metaphorical and analogical reasoning on an orthogonal perceptual axis, the scale refines Crombie's [3] taxonomy, empirically separating *symbolic depiction* from *structural mapping*. This distinction is consistent with experimental evidence that metaphor processing relies on right-hemisphere associative networks, whereas analogical mapping recruits fronto-parietal circuitry specialised for relational integration [65]. Third, the 8-FRSS enriches the cognitive-style literature [63] by treating style not as a *preference* for verbal versus visual processing, but as an *epistemic stance* that guides how data are selected, transformed, and warrant conclusions. For example, *Empirical-Deductive* thinkers resemble Riding's [42] "wholist–analytic" profile in their reliance on concrete data, yet they diverge in that they apply syllogistic rules rather than holistic gist extraction. The moderate correlations among the remaining six factors map onto *adaptive-toolbox* theories [66]: individuals appear to cultivate partially overlapping heuristics that can be flexibly combined to fit task demands. This mosaic supports an emerging consensus that cognitive diversity is not noise but a reservoir of strategies suited to environments of varying complexity [67].

The additional convergent validity study yielded high correlations between corresponding 8-FRSS dimensions and the Sternberg–Wagner thinking styles, providing robust criterion validity evidence for our instrument. These results demonstrate that the 8-FRSS captures reasoning orientations that align closely with established measures of mental self-government, further supporting the scale's applicability in both research and applied settings.

Even with these encouraging results, several limitations should be acknowledged. First, the sample consisted only of undergraduate students from three universities, limiting the generalizability of the results to broader cultural, educational, or professional settings. Second, the exclusive reliance on self-report measures increases the risk of response biases, such as social desirability, which future research could address by using alternative assessment methods (e.g., peer evaluations or behavioral tasks). Third, while the iterative item refinement improved psychometric properties, removing items based on statistical criteria may have narrowed the constructs' coverage. Fourth, the cross-sectional design prevents conclusions about the temporal stability of reasoning styles, highlighting the need for longitudinal designs and measurement invariance testing across diverse groups. Additionally, some subscales showed lower reliability and AVE values, suggesting the need for further scale refinement.

We conducted an exploratory factor analysis (EFA) using principal-axis factoring as the extraction method and an oblique rotation to allow the eight reasoning-style factors to correlate [68]. Average item communalities exceeded 0.65, indicating that most variance was common across items, and the analysis yielded a clear eight-factor solution that closely matched our theoretical model. Future studies could apply alternative extraction methods or rotations to confirm and extend these findings. Despite these considerations, this factor structure represents an important advance in operationalizing the complexity of human reasoning.

In educational settings, mapping students' positions within the three-axis space can inform adaptive instruction: inquiry-based labs may suit *Empirical-Inductive* thinkers, whereas case-based analogical teaching could engage *Analogical-Deductive* learners. In applied psychology and public policy, preliminary evidence from the EvA scale shows that epistemic styles predict vaccine uptake and susceptibility to health misinformation [52], future work should test whether 8-FRSS profiles offer similar or stronger predictive validity. The scale may also provide a human benchmark for emerging AI reasoning frameworks. Recent evaluations of large-language-model reasoning distinguish between deliberative (rule-based) and adaptive (pattern-inductive) strategies [69]. Embedding the 8-FRSS taxonomy into LLM evaluation protocols could clarify which human-like styles current models emulate and where systematic gaps remain.

The correlation results provide strong evidence for the concurrent validity of the Reasoning Styles Scale. Positive and statistically significant relationships ($p < .01$) were found with Sternberg's Thinking Styles framework, indicating that higher endorsement of reasoning styles aligns with corresponding thinking preferences. Strongest correlations emerged between analogical reasoning forms and legislative, executive, and judicial thinking styles ($r \approx .50$–0.61), confirming theoretical expectations. Moderate and lower yet significant correlations with other thinking styles further support the scale's validity while reflecting varying degrees of conceptual overlap. Overall, these findings affirm that the Reasoning Styles Scale effectively captures cognitive structures consistent with established models, thereby demonstrating concurrent validity.

All things considered, the 8-FRSS presents a theoretically informed and empirically based instrument for evaluating several facets of thinking. Drawing from philosophical insights into styles of reasoning and cognitive frameworks in psychology, this instrument offers a strong basis for investigating the complex structure of reasoning in many practical environments, including education, decision-making, and problem-solving, even if more study is required to enhance some subscales and extend validation to more varied groups.

Conclusion

In conclusion, this study developed and validated the 8-FRSS, a novel instrument grounded in a theoretical framework that distinguishes reasoning along three dimensions, Disposition (Empirical ↔ Hypothetical), Perception (Metaphorical ↔ Analogical), and Organization (Inductive ↔ Deductive), resulting in eight distinct reasoning styles. Our findings, supported by both EFA and CFA, indicate that the scale exhibits a robust factor structure and acceptable internal consistency across most dimensions. Key fit indices (e.g., CFI = 0.918, TLI = 0.901, RMSEA = 0.052) corroborate the scale's structural validity and suggest that it provides a clear and pragmatic method for distinguishing between different cognitive approaches, such as empirical-deductive versus metaphorical-inductive reasoning. An additional file provides the full 8-FRSS instrument and scoring structure [see Additional file 1].

Abbreviations

CFA	Confirmatory Factor Analysis
EFA	Exploratory Factor Analysis
EvA	Evidence-versus-Advice Scale
GPT	Generative Pre-trained Transformer
KMO	Kaiser-Meyer-Olkin
8-FRSS	8-Factor Reasoning Styles Scale

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40359-025-03320-9.

Supplementary Material 1: 8-Factor Reasoning Styles Scale (8-FRSS) Form. The 8-Factor Reasoning Styles Scale (8-FRSS) is a self-report questionnaire designed to measure reasoning styles across three cognitive axes (Organization, Disposition, and Perception). It contains 26 items rated on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The items align with eight distinct reasoning styles based on the intersections of the axes.

Supplementary Material 2

Acknowledgements

The datasets used in this study are not publicly accessible for the protection of personal data. Requests for the data used in this study may be directed to the author via email at volkan.duran8@gmail.com.

Author contributions

V.D. conceptualized and designed the research, developed the theoretical framework, generated and refined the scale items, conducted the data collection, performed all statistical analyses including Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and interpreted the results.

V.D. and F.Ç also wrote the entire manuscript, V.D. and F.Ç. prepared all figures and tables, and reviewed the final draft for submission.

Funding
Not applicable.

Data availability
The datasets used in this study are not publicly accessible for the protection of personal data. Requests for the data used in this study may be directed to the author via email at volkan.duran8@gmail.com.

Declarations

Ethic approval and consent to participate
All experimental procedures and protocols in this study were performed in accordance with the relevant guidelines and regulations (e.g., the Declaration of Helsinki). The study was approved by the Iğdır University Scientific Research and Publication Ethics Committee (approval reference: 2024/28, dated 18.1.2024). Written informed consent was obtained from all participants prior to data collection, and participants were assured of the confidentiality and anonymity of their responses. No identifiable personal information was collected.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 22 December 2024 / Accepted: 14 August 2025
Published online: 19 August 2025

References

1. Bueno O. Styles of reasoning: A pluralist view. Stud Hist Philos Sci. 2012;43:657–65.
2. Hacking I. Language, truth and reason 30 years later. Stud Hist Philos Sci. 2012;43(4):599–609.
3. Crombie AC. Styles of scientific thinking in the European tradition. Bloomsbury; 1994. pp. 1–3.
4. Hacking I. Language, truth and reason. In: *Rationality and relativism.* edn. Edited by Hollis M, Lukes S. Oxford: Blackwell; 1982: 48–66.
5. Hacking I. The accumulation of styles of reasoning. In: *Kant oder Hegel? Über Formen der Begründung in der Philosophie.* edn. Edited by von Dieter H. Stuttgart: Klett-Cotta; 1983: 453–465.
6. Hacking I. The laboratory style of thinking and doing. In.; 2007.
7. Hacking I. Scientific reason. Taiwan: NTU; 2009.
8. Sciortino L. What is a style of reasoning? Transversal: Int J Historiography Sci. 2023;15:1–2.
9. Duran V. Program Geliştirme modelleri, çeşitli Mantık Yaklaşımları ve Karmaşık sistemler. İstanbul: Mantık Derneği Yayınları; 2017.
10. Duran V, Özer B. Investigation of the reasoning styles of the university students. Disiplinlerarası Eğitim Araştırmaları Dergisi. 2017;1:1.
11. Duran V. Öğretmen Adaylarının Akıl Yürütme stilleri, bilişsel Çarpıtmaları ve Eleştirel Düşünme Eğilimlerinin incelenmesi. Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü; 2019.
12. Duran V, Şentürk Ş. Development of reasoning styles scale. Univers J Educational Res. 2019;7(5):1205–15.
13. Duran V, Mertol H. Investigation of the reasoning styles of the teacher candidates in terms of decision-making styles, learning modalities and gender. Eur J Contemp Educ. 2019;8(3):489–505.
14. Duran V, Ekici G. Investigation of reasoning styles and causal attributions for success of teacher candidates. OPUS Int J Soc Researches. 2020;16:5483–507.
15. Duran V, Budak Y. Reasoning styles model in the context of literature of proof schemes. Bridging theory and practices for educational sciences. edn. Lyon: Livre de Lyon; 2021. pp. 181–98.
16. Byrne RMJ. How people think about possibilities. Possibility Stud Soc. 2023;1(1–2):29–36.
17. Friedrich J, Fischer MH, Raab M. Issues in grounded cognition and how to solve them – the minimalist account. J Cognition. 2025;8(1):31.
18. Olsson H, Galesic M. Analogies for modeling belief dynamics. Trends Cogn Sci. 2024;28(10):907–23.
19. Wu CM, Meder B, Schulz E. Unifying principles of generalization: past, present, and future. Ann Rev Psychol. 2025;76(1):275–302.
20. Johnson-Laird PN, Khemlani SS, Goodwin GP. Logic, probability, and human reasoning. Trends Cogn Sci. 2015;19(4):201–14.
21. Johnson-Laird P. Deductive reasoning. Wiley Interdisciplinary Reviews: Cogn Sci. 2010;1:8–17.
22. Kazali E. Executive functions in inductive and deductive reasoning. J Exp Child Psychol. 2025;252:106144.
23. Keating DP, Demidenko I, Kelly D. Cognitive and neurocognitive development in adolescence. Reference module in neuroscience and biobehavioral psychology. edn.: Elsevier; 2019. p. B9780128093245236365.
24. Hayes BK, Pham J, Lee J, Perfors A, Ransom K, Desai SC. Changing your Mind about the data: updating sampling assumptions in inductive inference. Cognition. 2024;245:105717.
25. Huemer M. There is no pure empirical reasoning. Philos Phenomenol Res. 2017;95(3):592–613.
26. Reid DA, Knipping C. Proof in mathematics education: research, learning and teaching. Rotterdam: Sense; 2011.
27. Weber K. On the sophistication of Naïve empirical reasoning: factors influencing mathematicians' persuasion ratings of empirical arguments. Res Math Educ. 2013;15(2):100–14.
28. Yao X, Elia J. Connections between empirical and structural reasoning in technology-aided generalization activities. Int Electron J Math Educ. 2021;16(2):em0628.
29. Evans JSBT. Hypothetical thinking: dual processes in reasoning and judgment. New York: Psychology; 2007.
30. Magnani L. Abductive cognition. Berlin Heidelberg: Springer-; 2009.
31. Amsel E. Hypothetical thinking in adolescence: Its nature, development, and applications. In: *Adolescence: Vulnerabilities and Opportunities.* edn.; 2011: 86–113.
32. Draaisma D. Bellek Metaforları. İstanbul: Metis Yayınları; 2014.
33. Indurkhya B. Rationality and reasoning with metaphors. New Ideas Psychol. 2007;25:16–36.
34. Svačinova I. Reconstruction of metaphors in argumentation: A case study of lincoln's metaphor of swapping horses while crossing a stream. Cogency. 2014;6:67–89.
35. Ervas F, Rossi MG, Ojha A, Indurkhya B. The double framing effect of emotive metaphors in argumentation. Front Psychol. 2021;12:628460.
36. Johnson M. Metaphorical reasoning. South J Philos. 1983;21(3):371–89.
37. Ball LJ, Ormerod TC, Morely NJ. Spontaneous analogising in engineering design: A comparative analysis of experts and novices. Des Stud. 2004;25:495–508.
38. Bartha P. Analogy and analogical reasoning. In.; 2013.
39. Sauce B, Matzel LD. Inductive Reasoning. In: *Inductive Reasoning.* edn.; 2017.
40. Arnheim R. Görsel Düşünme. İstanbul: Metis Yayınları; 2007.
41. Goel V, Dolan RJ. Explaining modulation of reasoning by belief. Cognition. 2003;87:B11–22.
42. Riding RJ. On the nature of cognitive style. Educational Psychol. 1997;17(1–2):29–49.
43. Sternberg RJ. Thinking styles. New York: Cambridge University Press; 1997.
44. Ponce-Garcia E, Kennison S. Cognitive style. Cross cultural encyclopedia. edn. Edited by Keith K; 2013.
45. Rani P, Agarwal N. Thinking styles: an overview. In.; 2020.
46. Galotti KM, Ciner E, Altenbaumer HE, Geerts HJ, Rupp A, Woulfe J. Decision-making styles in a real-life decision: choosing a college major. Pers Indiv Differ. 2006;41(4):629–39.
47. D'Zurilla TJ, Nezu AM, Maydeu-Olivares A. Social problem solving: Theory and assessment. In: *Social problem solving: Theory, research, and training.* edn. Edited by Chang EC, D'Zurilla TJ, Sanna LJ. Washington, DC: American Psychological Association; 2004.
48. El-Sabagh HA. Adaptive e-learning environment based on learning styles and its impact on development students' engagement. Int J Educational Technol High Educ. 2021;18(1):1–24.
49. Fowler R. The Language of George Orwell. Macmillan; 1995.
50. Buluş M. Assessment of Thinking Styles Inventory, Academic Achievement and Student Teacher's Characteristics. Eğitim ve Bilim; 2006.
51. Fabio RA, Verzì D, Gangemi A. A contribute to the default-interventionist and parallel accounts in deductive reasoning. The effect of decisional styles on logic and belief. J Gen Psychol. 2024;151(2):209–22.

52. Shin H, Shah P, Preston SD. The reasoning through evidence versus advice (EvA) scale: scale development and validation. J Pers Assess. 2024;106(5):681–95.
53. Akinci C, Sadler-Smith E. Assessing individual differences in experiential (intuitive) and rational (analytical) cognitive styles. Int J Selection Assess. 2013;21(2):211–21.
54. Zhang L-F, Sachs J. Assessing thinking styles in the theory of mental self-government: A Hong Kong validity study. Psychol Rep. 1997;81(3):915–28.
55. Costello AB, Osborne J. Best practices in exploratory factor analysis: four recommendations for getting the most from your analysis. Practical Assess Res Evaluation 2005, 10(1).
56. Schreiber JB, Nora A, Stage FK, Barlow EA, King J. Reporting structural equation modeling and confirmatory factor analysis results: A review. J Educational Res. 2006;99(6):323–38.
57. Çokluk Ö, Şekercioğlu G, Büyüköztürk Ş. Sosyal bilimler Için Çok değişkenli Istatistik SPSS ve LISREL Uygulamaları. Ankara: Pegem Akademi; 2018.
58. Hair JF Jr., Hult GTM, Ringle CM, Sarstedt M. A primer on partial least squares structural equation modeling (. PLS-SEM): Sage;; 2021.
59. Stanovich KE. The bias that divides us: the science and politics of Myside thinking. MIT Press; 2021.
60. Wei Y, Long D, Fu L. The influence of intuitive-analytical cognitive styles on entrepreneurial decision-making logic: moderated by environmental uncertainty. Sage Open 2024, 14(3).
61. Drummond C, Fischhoff B. Development and validation of the scientific reasoning scale. J Behav Decis Mak. 2017;30(1):26–38.
62. Di Nitto M, Durante A, Torino F, Bolgeo T, Damico V, Ghizzardi G, Zerulo SR, Alvaro R, Vellone E, Biagioli V. Validity and reliability of the self-care of chronic illness inventory and self-care self-efficacy scale in patients living with cancer. J Adv Nurs 2025:jan16823.
63. Kozhevnikov M. Cognitive styles in the context of modern psychology: toward an integrated framework. Psychol Bull. 2007;133(3):464–81.
64. Oliver M. What styles of reasoning are important in primary english?? Curriculum J. 2021;32(4):704–21.
65. Vartanian O. Dissociable neural systems for analogy and metaphor: implications for the neuroscience of creativity. Br J Psychol. 2012;103(3):302–16.
66. Gigerenzer G, Selten R. Bounded rationality: the adaptive toolbox. MIT Press; 2001.
67. Kahneman D, Klein G. Conditions for intuitive expertise: A failure to disagree. Am Psychol. 2009;64:515–26.
68. Goretzko D, Pham TTH, Bühner M. Exploratory factor analysis: current use, methodological developments and recommendations for good practice. Curr Psychol. 2021;40:3510–21.
69. Zhao W, Sui X, Guo J, Hu Y, Deng Y, Zhao Y, Liu T. Trade-offs in large reasoning models: an empirical analysis of deliberative and adaptive reasoning over foundational capabilities. ArXiv Preprint 2025:arXiv:250317979.

Publisher's note