Generalizations in Analogical Argument

Wensheng Zhu

School of Philosophy
Zhejiang University
Hangzhou, Zhejiang Province, China
zws_@zju.edu.cn

Huaxin Huang

School of Philosophy
Zhejiang University
Hangzhou, Zhejiang Province, China
rw211@zju.edu.cn

Abstract: This paper presents a generalization-centered framework for analyzing analogical arguments. By examining how analogical generalization is treated across various research paradigms, it highlights its role in modeling both similarity and relevance. Unlike deductive or inductive generalizations, analogical generalization is empirical, hypothetical, and context-sensitive, underscoring the *sui generis* nature of analogical arguments. Building on this foundation, the paper extends the classical scheme and introduces a set of critical questions anchored in generalization. A detailed case study illustrates the framework's practical value in identifying argument structure, modeling context sensitivity, and assessing the cogency of analogical arguments.

Résumé: Cet article présente un cadre d'analyse des arguments analogiques centré sur la généralisation. En examinant comment la généralisation analogique est traitée dans différents paradigmes de recherche, il met en lumière son rôle dans la modélisation de la similarité et de la pertinence. Contrairement aux généralisations déductives ou inductives, la généralisation analogique est empirique, hypothétique et contextuelle, soulignant ainsi la nature sui generis des arguments analogiques. L'article s'appuie sur ce fondement pour étendre le schéma classique et introduire un ensemble de questions critiques ancrées dans la généralisation. Une étude de cas détaillée illustre l'intérêt pratique de ce cadre pour identifier la structure argumentative, modéliser la sensibilité au contexte et évaluer la puissance des arguments analogiques.

Keywords: analogical argument, analogical generalization, context sensitivity, relevance, similarity

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1. Introduction

Analogy is a fundamental mode of human cognition, deeply embedded in our reasoning processes. It plays a central role not only in everyday thought but also in scientific inquiry, education, and legal reasoning. Analogical thinking allows individuals to build a conceptual bridge from the known to the unknown, drawing on prior knowledge to interpret unfamiliar situations. As Bartha defines it (2010, p. 1), an "analogy" is a comparison between two objects or systems that highlights respects in which they are considered similar. "Analogical reasoning" refers to any form of thinking that relies on such comparisons. As explicit representation of this reasoning process, an "analogical argument" identifies presumably accepted similarities between two systems to support the conclusion that some further similarity also holds.

This study examines analogical arguments that can be systematically analyzed and evaluated, with a particular focus on their structural features. From the perspective of informal logic, a well-established scheme for analogical reasoning was formulated by Walton (2008, p. 58) and is typically presented as follows:

1. Major Premise: Generally, case C_1 is similar to case C_2.
2. Relevant Similarity Premise: The similarity between C_1 and C_2 observed so far is relevant to the further similarity that is in question.
3. Minor Premise: Proposition A is true (false) in case C_1.
4. Conclusion: Proposition A is true (false) in case C_2.

In this scheme, C_1 and C_2 denote two specific cases. The structure reflects the intuition that, when two cases share a certain degree of similarity that is relevant to a given proposition A, it is reasonable to infer that A applies to both cases in a comparable way.

In addition, a set of critical questions has been proposed for evaluating the cogency of analogical arguments framed within this

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classical scheme (Walton et al. 2008, p. 62):

- CQ1: Is A true (false) in C_1?
- CQ2: Are C_1 and C_2 similar, in the respects cited?
- CQ3: Are there important differences (dissimilarities) between C_1 and C_2?
- CQ4: Is there some other case C_3 that is also similar to C_1 except that A is false (true) in C_3?

These questions not only complement the basic structure of the scheme but also provide a foundational framework for the systematic evaluation of analogical reasoning. By assessing the relevance and sufficiency of the cited similarities, the justificatory status of the proposition in the source case, and the existence of possible counterexamples, this framework enables a structured appraisal of the cogency[1] of a given analogical argument.

However, subsequent research has shown that the basic scheme continues to face several significant limitations. Walton himself later acknowledged that a core challenge lies in modeling and objectively assessing similarity (2014). Addressing this issue, Macagno et al. analyzed different types of similarity and their respective implications for relevant similarity and the projection of conclusions (2017). Walton and Hyra further examined how distinct argumentative contexts, particularly persuasive versus deliberative ones, impose different normative demands on the nature and function of similarity in analogical arguments (2018). More recently, Guarini highlighted the role of emotional factors in shaping both the selection of source

[1] The concept of "cogency" is central to the evaluation of arguments in logic and critical thinking, particularly for non-deductive forms of reasoning such as inductive inference, analogical reasoning, and causal argumentation. Within the framework of informal logic, Govier, in *A Practical Study of Argument*, defines a cogent argument as one whose premises are rationally acceptable and properly connected to the conclusion (2010, p. 114). The premises are properly connected if they are relevant to the conclusion and, taken together, provide good grounds for accepting it.

domains and the perception of similarity (2023). Collectively, these studies indicate that modeling and evaluating similarity, especially in a context-sensitive manner, is essential for the cogent construction and assessment of analogical arguments.

While the studies noted above underscore the importance of similarity and context in evaluating analogical arguments, most of them describe the phenomenon rather than provide clear methods for modeling it. To address this gap, Walton proposed the use of "story schemes" to model similarity (2012). These scripts represent abstract sequences of events shared across different cases. In doing so, they make the basis of similarity more explicit, thereby rendering the analogical argument easier to follow and more persuasive. A story scheme, in this sense, is not merely a direct comparison between two cases, but a generalization[2] that both cases instantiate. This generalization does more than describe the similarity but also helps explain how the premise of similarity supports the conclusion. From this perspective, generalization plays a central role in constructing and evaluating analogical arguments.

It is worth noting that, in modeling similarity, research in formal logic and cognitive science offers more systematic and technical approaches. In these fields, generalization is often regarded as a core strategy for representing similarity. For example, the Heuristic-Driven Theory Projection (HDTP) treats generalization as a means of capturing the shared structure between analogues, which then serves as the basis for transferring knowledge from one case to another (Schmidt et al. 2014). Likewise, in Structure Mapping Theory (SMT) (Falkenhainer et al. 1989; Gentner 1983), the extraction of a common relational structure between analogues can also be understood as a form of generalization. In these accounts, generalization operates both as a technical method and as a representational tool

[2] According to the *Oxford English Dictionary*, "generalization" in sense 1.a is defined as "the act or process of forming general concepts from specific instances by abstracting common properties" (Oxford English Dictionary 2024).

that directly shapes the reasoning process and the outcomes of analogical arguments. As such, it enhances the structural coherence and interpretability of computational models of analogy.

At the same time, the emergence of third-generation artificial intelligence, particularly the growing interest in the analogical reasoning capabilities of large language models (LLMs) (Lewis and Mitchell 2024; Mitchell 2021; Mitchell et al. 2023; Opiełka et al. 2025; Webb et al. 2023), has renewed attention to the role of generalization. While recent studies have shown that LLMs can perform well on certain analogy tasks (Webb et al. 2023), Lewis and Mitchell contend that current models still lack genuine abstract analogical reasoning abilities (2024). In their view, failure on zero-shot tasks often reflects a capacity to detect surface-level patterns in training data rather than an understanding of the deeper similarities on which analogical reasoning depends. These deeper similarities are precisely what generalization is intended to capture. From this AI-oriented perspective, generalization serves not only as a key benchmark for assessing the reasoning capacities of LLMs but also as an important lens through which to examine how such models process and represent analogical arguments.

However, current theories of analogical argument give relatively little attention to the role of generalization. One possible reason is that, within the tradition of logic, generalization is often associated with deductive or inductive reasoning. From this standpoint, its use might be seen as undermining the distinctiveness of analogical argument as a separate mode of reasoning. We contend, however, that this is not a sufficient reason to overlook its importance. What warrants closer examination is the nature of "analogical generalization" and how it differs from more familiar forms of deductive rules or inductive generalizations. If analogical generalization is indeed distinct in both form and function, it may play a unique logical and cognitive role within analogical arguments.

Based on this view, the present study examines generalization in analogical argument with respect to both its logical structure and its

cognitive mechanism. The main objectives are:

1. The structural role of analogical generalization within the argument scheme. Does it function as a key representation of analogical argument and as an essential component in constructing its scheme? Can it enable more precise and context-sensitive modeling of similarity?

2. The distinctiveness of analogical generalization compared with traditional forms of generalization (e.g., deductive rules or inductive generalizations). What unique inferential properties or cognitive functions does this distinctiveness contribute to analogical reasoning?

3. The potential of analogical generalization as a tool or anchor for evaluation. Can it support the development of a more systematic and fine-grained framework for assessing analogical arguments?

To this end, Sections 2 through 4 examine how various scholars have understood, defined, and applied generalization in analogical argument. While these discussions arise from different research paradigms, they share the common goal of clarifying the role and status of generalization in analogical reasoning. Building on this foundation, Section 5 offers a more precise account of the definition and function of analogical generalization and introduces a generalization-based scheme for analogical argument by extending the classical model. Section 6 analyzes the distinctive features of analogical generalization, justifying the treatment of analogical reasoning as a *sui generis*[3] form of argument and explaining how these features relate to its defeasibility and associated risks. Section 7 develops a set of critical questions tailored to analogical generalization, with the goal of constructing a more systematic and practically applicable

[3] *Sui generis* accounts are characterized by identifying features of an inference that cannot be reduced to abductive, deductive, or inductive reconstruction (Juthe 2020).

framework for evaluating analogical arguments. Finally, Section 8 applies this framework in a detailed case study of analogical reasoning in Darwinian evolutionary theory, considering both supportive and critical perspectives to illustrate the analytical process and the evaluative advantages of the proposed model.

2. Generalization: Similarity in analogical argument

As noted in the introduction, Walton proposed modeling similarity in analogical arguments through story schemes (2012), which are generalizations of shared structures across events. This approach, however, is not unique to informal logic; it appears across multiple research paradigms in the study of analogical reasoning. In cognitive science, for example, Gentner's well-known SMT characterizes analogy as the alignment of relational structures between domains (1983). Likewise, in formal logic, models such as HDTP rely on generating shared structures to capture analogical similarity (Schmidt et al. 2014). In both frameworks, the central mechanism involves extracting generalized properties, rules, or relations from the source and target domains, and using these generalizations to represent their structural similarity. In this sense, generalization functions as an abstract representation of cross-domain similarity and forms the basis for the similarity premise in analogical arguments.

A representative example of this approach is the HDTP framework proposed by Schmidt et al. (2014). HDTP is a logic-based model of analogical reasoning grounded entirely in first-order logic, with clearly defined syntax, semantics, and computational procedures. It analyzes the source and target domains to identify shared structural patterns and then transfers knowledge from the source to the target on the basis of these patterns. This process is designed to generate new theories or hypotheses, thereby supporting creative reasoning and problem solving.

Within this framework, generalization plays a central role both conceptually and technically, serving as the key mechanism for

representing similarity between domains. In HDTP, generalization is defined as the process of identifying structural commonalities between two domains in the course of analogical reasoning. By generalizing formulas from both domains, the model generates an abstract yet unified structure that captures their shared features. The formal definition of this process is given as follows (Schmidt et al. 2014):

> Definition 1 (Substitutions). A substitution on terms is a partial function, mapping variables to terms, formally represented by $\tau = \{X_1/t_1, \ldots, X_n/t_n\}$ (provided $X_i \neq X_j$ for $i, j \in \{1, \ldots, n\}, i \neq j$). We say τ acts on variables $X_1, \ldots, X_n$. An application of a substitution τ on a term is defined by simultaneously replacing all occurrences of the variables $X_1, \ldots, X_n$ and thus:
>
> - $apply(X, \tau) = \begin{cases} t' & if\ X/t' \in \tau \\ X & otherwise \end{cases}$
> - $apply(f(t_1, \ldots, t_m), \tau) = f(apply(t_1, \tau), \ldots, apply(t_m, \tau))$
>
> Definition 4 (Instance and Anti-Instance). A term t' is an instance of t and t is an anti-instance of t', if there is a substitution τ such that application of τ on t' results in t. In this case we write $t \overset{\tau}{\rightarrow} t'$ or simply $t \rightarrow t'$.
>
> Definition 8 (Generalization). A generalization for a pair of terms $\langle s, t \rangle$ is a triple $\langle g, \tau, v \rangle$ with a term g and substitutions τ, v such that $g \overset{\tau}{\rightarrow} s$ and $g \overset{v}{\rightarrow} t$.

As the definition indicates, a generalization in HDTP is represented as a triple consisting of: (1) a newly generated term that generalizes two input terms s and t, and (2) two substitution mappings that transform this general term back into the original terms. In this way, generalization encompasses not only the abstract representation of structural features, such as shared properties or rules, between the source and target domains, but also the procedural aspect of how

such a representation is constructed.

Moreover, the HDTP framework provides a formal account of the conditions under which a generalization in analogical reasoning should be regarded as a "preferred generalization" (Schmidt et al. 2014):

> Definition 12 (Preferred Generalization). A preferred generalization $\langle g, \tau, v \rangle$ is a least general generalization for the pair of terms s and t such that there is no other least general generalization that has less complexity and τ and v contain only the minimal amount of basic renaming substitutions required at their beginning.

It is thus evident that, in HDTP, generalization functions as a means of capturing the shared structure between formulas in the source and target domains, forming the foundation for establishing the analogical mapping.

Based on this definition, HDTP further analyzes a well-known analogy in physics, namely the Rutherford Analogy:

> Example 1 (Rutherford Analogy). In the Rutherford Analogy, the solar system serves as the source domain, while the Rutherford atom model functions as the target domain. The analogy highlights a structural correspondence between the two systems: in the solar system, planets revolve around the sun under gravitational attraction while maintaining a non-zero distance; in the atom model, lightweight electrons revolve around the positively charged nucleus due to the Coulomb force, likewise without collapsing into it (Schmidt et al. 2014).

HDTP provides a logical formalization of the following features (Schmidt et al. 2014), in which both the solar system and the atom are characterized by:

- α_1: $mass(sun) > mass(planet)$,
- α_2: $mass(planet) > 0$,
- α_3: $\forall(T: time)$: $gravity(planet, sun, T) > 0$,
- α_4: $\forall(T: time)$: $dist(planet, sun, T) > 0$.

- β_1: $mass(nucleus) > mass(electron)$,
- β_2: $mass(electron) > 0$,
- β_3: $\forall(T: time)$: $coulomb(electron, nucleus, T) > 0$,
- β_4: $\forall(T: time)$: $dist(electron, nucleus, T) > 0$.

From this, the corresponding anti-instances and substitutions can be derived:

- A_1: $mass(X) > mass(Y)$, where $\tau_1 = \{X/sun, Y/planet\}$ and $\nu_1 = \{X/nucleus, Y/electron\}$,
- A_2: $mass(Y) > 0$, where $\tau_2 = \{Y/planet\}$, $\nu_2 = \{Y/electron\}$,
- A_3: $\forall(T: time)$: $f_1(Y, X, T) > 0$, where $\tau_3 = \{X/sun, Y/planet, f_1/gravity\}$, $\nu_3 = \{X/nucleus, Y/electron, f_1/coulomb\}$,

A_4: $\forall(T: time)$: $dist(Y, X, T) > 0$, where $\tau_1 = \{X/sun, Y/planet\}$, $\nu_1 = \{X/nucleus, Y/electron\}$.

This yields the following generalization for the given case:

- $\langle A_1, \tau_1, \nu_1\rangle$, $\langle A_2, \tau_2, \nu_2\rangle$, $\langle A_3, \tau_3, \nu_3\rangle$, $\langle A_4, \tau_1, \nu_1\rangle$

These generalizations function as empirical representations of the shared properties and relationships between the solar system and the atom. They capture the experiential similarities between the two systems, particularly with respect to mass relationships, force interactions, and distance constraints.

In fact, the idea of capturing structural similarity between analogues through generalization is largely influenced by SMT (Gentner 1983). As a foundational account of analogical reasoning in cognitive psychology, SMT has had a lasting impact and is supported by extensive experimental evidence. Although the theory does not explicitly use the term "generalization" to define similarity, its core mechanism involves extracting a common relational structure between two domains, which is functionally equivalent to generating a

generalization. According to SMT, the essence of analogy lies in identifying correspondences between the relational structures of two situations. This shared, abstract structure then provides the basis for uncovering further similarities and systematic mappings between the source and target.

Within the paradigm of informal logic, as noted earlier, Walton proposed a hybrid model that combines analogical arguments with story schemes as a means of analyzing similarity (2012). A story scheme consists of variables, with individual stories treated as specific instances of a more abstract schema. For example, a concrete story might describe someone entering a restaurant and placing an order, while the corresponding abstract scheme depicts a person entering a place and performing an action. In this sense, a story scheme functions as an abstract generalization of familiar sequences of events and actions, helping us identify and construct similarities between cases. This approach, which uses variable substitution to capture abstract patterns, closely parallels the generalization processes found in both formal logic and cognitive science, where similarity between analogues is represented through structural abstraction.

Across these diverse research paradigms, "generalization" is consistently understood as the process of abstracting shared relations and features from specific cases. It serves to capture the commonalities between the source and target domains. Because similarity is the core premise of an analogical argument, its acceptability and its relevance to the conclusion directly determine the argument's cogency. As a structured representation of this similarity, a generalization can serve as the similarity premise in an analogical argument; that is, case C_1 and case C_2 are similar under a given generalization.

3. Generalization: Relevance in analogical argument

However, beyond serving as the similarity premise in analogical arguments, "generalization" may also play additional roles. As noted in the introduction, Walton's notion of story schemes appears to

extend beyond simply modeling similarity. It also reflects, to some extent, the connection between the similarity premise and the analogical conclusion, since the events, actions, phenomena, and outcomes embedded in a story are typically causally or explanatorily related. In this sense, a generalization does more than represent surface-level similarity, it also helps articulate the internal structure linking the premise to the conclusion. Indeed, some scholars have approached analogical generalization from a rule-based perspective, treating it as a potential rule or principle that underlies and supports the inference from premise to conclusion.

Before proceeding, it is necessary to clarify the fundamental concept of "relevance". This dimension is indispensable for evaluating the cogency of analogical arguments. In *A Practical Study of Argument*, Govier offers a systematic account of relevance (2010), distinguishing three basic types: positive relevance, negative relevance, and irrelevance. She writes:

> A statement A is positively relevant to another statement B if and only if the truth of A counts in favor of the truth of B. A statement A is negatively relevant to another statement B if and only if the truth of A counts against the truth of B. A statement A is irrelevant to another statement B if and only if it is neither positively relevant nor negatively relevant to B (Govier 2010, pp. 147–48).

In other words, two statements are relevant if the truth value of A has some bearing on our judgment about the truth value of B. That is, A provides some form of evidence or reason for accepting or rejecting B.

In an analogical argument, the notion of "relevance" is embodied in the relevant similarity premise, which states that the observed similarities between the source and target domains must be relevant to the further similarity claimed in the conclusion (Walton et al. 2008, p. 58). The issue of relevance in analogical reasoning has been the subject of sustained discussion. Weitzenfeld, for example, emphasizes that similarity alone carries no argumentative force; what

matters is the positive correlation between the cited similarity and the property projected onto the target domain (Weitzenfeld 1984; Davies 1988). Similarly, Guarini argues that what truly supports an analogical argument is not the quantity of similarities but the presence of those that are relevant to the conclusion (2004). For instance, although a red apple and a red ball share the property of being red, one cannot infer that the ball is edible simply because the apple is, since color is not relevant to edibility in this case. This is precisely why Walton's scheme includes the premise of relevant similarity: to ensure that the analogy rests on features that genuinely support the projected conclusion.

Relevance is not only a key concern in informal logic but also a central concept in the cognitive science paradigm of analogical reasoning. One of the most influential models in this regard is Hesse's two-dimensional framework (Hesse 1966), which distinguishes between horizontal and vertical relations in analogical arguments. Horizontal relations represent the observed similarities between the source and target domains, whereas vertical relations capture the internal relevance between the known features in the source and the inferred features in the target. According to this model, a conclusion from the source can be justifiably projected onto the target only if there is vertical relevance linking the observed similarities to the projected conclusion.

Similarly, in Bartha's articulation model (Bartha 2010), relevance, specifically in the form of what he terms "prior association", is treated as a crucial precondition for transferring conclusions from source to target. The model holds that a strong analogical argument must establish a clear link between the relevant similarities already observed in the source and the further similarities anticipated in the target. This prior association provides a reason to expect that the same type of connection can be found or inferred in the target domain.

Since relevance captures the connection between the similarity observed in the analogues and the conclusion drawn, it is often

expressed as a rule linking two statements. Such a rule may take various forms, whether logical, causal, statistical, or otherwise dependent on the context. Moreover, some scholars have argued that these rules, which articulate the relevance in analogical arguments, can themselves be understood as a form of analogical generalization.

Understanding analogical generalization from a rule-based perspective typically involves constructing abstract representations of rules or principles that can be applied in analogical reasoning. This approach enables the transfer of existing relevant rules from the source domain to the target domain, thereby bridging the gap between similarity generalizations as empirical observations and conclusions as hypotheses. This idea is reflected in the work of scholars such as Ashley (1991), Ohkawa (1992), and Godden (2021), both in analogical computation and in formal logic.

Ashley analyzed how past cases provide analytical frameworks for interpreting current cases, identifying three such frameworks: generalization, constrained search, and comparative evaluation. With respect to generalization, he defined it as "a generalization may be a rule that can be applied deductively to solve or classify new problems, or it may be a causal explanation of the result in the case that can be mapped onto a problem analogically" (1991, p. 754). He further noted that "the generalizations identify the parts of a problem that are important and provide a procedure and warrant for reaching a conclusion" (1991, p. 754). In this view, a generalization functions as a causal explanation that bridges the premise and the conclusion, providing a rule through which the observed similarity can be used to justify a relevant conclusion.

Not only Ashley but also many other scholars have interpreted generalization in analogical argument in a similar way. Ohkawa defines generalization as the process of formulating specific principles from instances under the guidance of an existing set of rules, replacing constants with variables to generate new rules. In this view, generalization involves deriving new rules from specific instances that meet the criteria of similarity, relevance, generality, and applicability

(Ohkawa et al. 1992).

Similarly, Godden and Grey propose a "generalization rule" in their formal model of analogical argument, which is based on grounding relations (2021):

$$\text{if } [Pa] \leftarrow \Gamma, \text{ then } \forall x\big(\wedge \Gamma(a/x) \supset [Px] \leftarrow \Gamma(a/x)\big).$$

Here, Γ represents a set of facts, $\wedge \Gamma$ denotes the conjunction of elements in Γ, and P signifies the target conclusion property in an analogical argument. In their account, analogical generalization is likewise grounded in known rules from the source domain, represented as $[Pa] \leftarrow \Gamma$. By replacing instances with variables, this approach formulates a general rule for analogical argument, aiming to link the premise facts to the target fact and thereby support the argument's cogency.

From this perspective, analogical generalization arises from factual relationships and rules in the source domain. To transfer the target conclusion from the source to the target domain, it must be assumed that the rule governing the source domain also applies to the target domain. This assumption yields a new generalization, namely a potentially shared rule between the two domains within an analogical argument. In this view, analogical generalization is derived from empirical facts but extended into a hypothetical generalization, thereby bridging the gap between similarity generalization as an empirical observation and the analogical conclusion as a hypothetical conjecture. In essence, this form of analogical generalization represents the relevance between the premises and the conclusion in an analogical argument.

Moreover, analogical generalizations representing relevance can also be constructed through substitution rules. The classic Example 1 similarly illustrates how such a relevant analogical generalization can be generated.

In the previous section, we identified a set of generalizations and substitution chains that represent the structural similarities between

the solar system and the Rutherford model of the atom. In addition, the source domain exhibits the following features:

- α_5: $\forall(T: time, O_1: sun, O_2: planet): dist(O_2, O_1, T) > 0 \wedge gravity(O_2, O_1, T) > 0 \rightarrow centrifugal(O_2, O_1, T) = -gravity(O_2, O_1, T)$,
- α_6: $\forall(T: time, O_1: sun, O_2: planet): mass(O_1) > 0 \wedge mass(O_2) > 0 \wedge dist(O_2, O_1, T) > 0 \wedge centrifugal(O_2, O_1, T) < 0 \rightarrow revolves\_around(O_2, O_1)$.

These laws capture the key characteristics of the solar system that are suitable for generalization. Using the substitution chains applied earlier to generate similarity-based generalizations, we can likewise derive a generalized representation of these features:

- γ_1: $\forall(T: time): dist(Y, X, T) > 0 \wedge f_1(Y, X, T) > 0 \rightarrow centrifugal(Y, X, T) = -f_1(Y, X, T)$
- γ_2: $\forall(T: time): mass(X) > 0 \wedge mass(Y) > 0 \wedge dist(Y, X, T) > 0 \wedge centrifugal(Y, X, T) < 0 \rightarrow revolves\_around(Y, X)$

These generalizations establish a direct link between similarity and conclusion, forming the basis for analogical transfer. They capture the relevance that enables the transfer of properties from the source domain to the target domain. Consequently, constructing generalizations through substitution operations is an effective way to represent the relevance between analogical premises and conclusions.

However, it is important to note a key distinction between this type of generalization and similarity generalization. A central mechanism of generalization as relevance lies in the transition from empirical facts to hypothetical conjectures. By extending the scope of applicability, specifically by generalizing a rule originally confined to the source domain so that it encompasses both the source and target domains, the arguer transforms concrete empirical facts from the source into a cross-domain hypothesis. This is because the

connection between the similarity premise and the analogical conclusion in the target domain remains hypothetical and lacks empirical confirmation. For this reason, we regard generalization as a representation of relevance to be potential in nature, a form of hypothetical conjecture.

This mechanism also reveals potential risks in treating generalization as a representation of relevance. On one hand, if a reasoner mistakenly treats a hypothetical generalization as if it were empirically grounded, the result may be an overestimation of the argument's cogency. On the other hand, if the provisional nature of a hypothetical generalization is overlooked and the associated rule is applied too broadly, the outcome may be overgeneralization, which significantly weakens the strength of the analogical argument.

Therefore, whether generalization functions as a representation of similarity or of relevance, it can have a substantial impact on the cogency of the analogical argument.

4. Generalization: A derived outcome of analogical argument

Moreover, our review of the literature indicates that some researchers appear to apply generalization at a later stage in the analogical process, namely after the analogical conclusion has been drawn, where the generalization emerges as a derivative of the analogy.

In the previous section, we referred to Bartha's articulation model as developed in his work on analogical reasoning (Bartha 2010). Notably, his account also includes a discussion of generalization. According to Bartha, a strong analogical argument must exhibit the potential for generalization, meaning that there should be no compelling reason to block the extension of the prior association from the source domain to the target domain. In his view, a good analogy must both possess and reflect a reasonable prospect of generalization, and when such potential exists, the overall cogency of the argument is significantly enhanced. On this account, assessing analogies requires examining horizontal similarities and differences, not to measure

overall resemblance, but to determine whether these features support or hinder the extension of the analogy. In this sense, generalization serves as the ultimate aim of analogical reasoning: a powerful hypothesis that the analogy invites us to consider.

Moreover, Bartha argues that generalization can take several distinct forms. Analogical arguments based on feature matching typically lead to the discovery or extension of a kind; those grounded in formal similarity yield shared mathematical representations; and analogies based on parameter similarity give rise to, or reinforce, unifying principles and invariant relations. When evaluating the similarities and differences between source and target domains, these different forms of generalization should be carefully considered (Bartha 2010). On his account, kinds, shared mathematical structures, unification, and invariance represent distinct modes of generalization that can emerge from analogical reasoning, each shaping how an analogical argument should be assessed.

However, this raises a potential tension: if generalization is itself the conclusion of an analogical argument, how can it also play a role in evaluating the argument? From Walton's perspective, particularly as reflected in his set of critical questions, evaluation focuses on the premises and reasoning process of the analogy, including similarity, relevant differences, source domain features, and possible alternative analogies (Walton et al. 2008). The conclusion, by contrast, is not typically considered part of what determines the argument's cogency. This suggests the need to examine more closely how Bartha treats these three distinct forms of generalization.

For analogical arguments based on feature matching, Bartha argues that "a correlative analogical argument is cogent if it provides reason to infer that the source and target domains are likely to belong to a common kind, corresponding to a common nature that is responsible for the cited and hypothetical similarities" (2010, p. 198). A classic example is Franklin's analogy between lightning and electrical fluid:

> Example 2 (Electrical fluid and lightning). Electrical fluid agrees with lightning in these particulars: 1. Giving light. 2. Color of the light. 3. Crooked direction. 4. Swift motion. 5. Being conducted by metals. 6. Crack or noise in exploding. 7. Subsisting in water or ice. 8. Rending bodies it passes through. 9. Destroying animals. 10. Melting metals. 11. Firing inflammable substances. 12. Sulphureous smell. The electrical fluid is attracted by points. We do not know whether this property is in lightning. But since they agree in all the particulars where we can already compare them, is it not probable they agree likewise in this? (Bartha 2010, p. 197)

Drawing on a rich, distinctive, and concentrated set of shared features between electrical fluid and lightning, Franklin inferred that additional feature matches were likely to hold between them. According to Bartha, although it is not known whether the property of "being attracted to pointed objects" is causally related to the twelve previously identified shared features, the argument provides sufficient grounds for inferring that electrical fluid and lightning belong to the same kind, thereby exhibiting the potential for generalization. Once they are regarded as members of the same kind, it becomes plausible to attribute the property of "being attracted to pointed objects" to lightning as well. In this view, the unification of electrical fluid and lightning under a common kind constitutes a generalization that supports the analogical conclusion: lightning, like electrical fluid, is attracted to pointed objects.

However, this generalization seems less like the ultimate conclusion of the analogical argument and more like a premise or intermediate step in the reasoning process leading to that conclusion.

For analogical arguments based on formal similarity, the abstraction of a shared mathematical structure makes it possible to establish a formal parallel between two domains, whether in the articulation of laws or the description of empirical phenomena (Bartha 2010, p. 209). The central idea of formal analogy is that two sets of laws can be unified under a common mathematical structure, obtained by

assigning different interpretations to the symbols within that shared framework.

This type of analogy is common in physics. Maxwell described it as a "resemblance in form" between "the laws of one science and those of another" (1890, p. 156). He identified numerous formal analogies among heat, fluid flow, and inverse-square law forces. A representative example is discussed by Bartha (2010, p. 208):

> Example 3 (Attractive forces and heat conduction). The laws of the conduction of heat in uniform media appear at first sight among the most different in their physical relations from those relating to attractions. The quantities which enter into them are temperature, flow of heat, conductivity. The word force is foreign to the subject. Yet we find that the mathematical laws of the uniform motion of heat in homogeneous media are identical in form with those of attractions varying inversely as the square of the distance. We have only to substitute source of heat for center of attraction, flow of heat for accelerating effect of attraction at any point, and temperature for potential, and the solution of a problem in attractions is transformed into that of a problem in heat.

This correspondence can be illustrated more formally. The electric field $E(x)$ generated by an electric potential $\phi(x)$ at a point x in a system of charged particles is given, for a constant k_1, by $E(x) = -k_1 \nabla \phi(x)$. Similarly, the heat flow (or heat flux vector) $H(x)$ resulting from a temperature distribution $T(x)$ is expressed, for a constant as k_2, as $H(x) = -k_2 \nabla T(x)$. Both share the same mathematical form, $A(x) = -k \nabla f(x)$, revealing a formal correspondence between the laws governing electric fields and those describing heat conduction.

Based on this generalization in terms of mathematical form, two distinct physical systems can be interpreted within a unified theoretical framework. Consequently, the problem of gravitation can be addressed through the lens of heat conduction. In this instance, the generalization once again functions as a premise that underpins the

analogical conclusion. Moreover, it operates in a classificatory capacity, subsuming the two systems under a shared explanatory structure and thereby advancing the analogical reasoning process.

For analogical arguments based on parametric similarity, the source and target domains are connected through a sequence of cases that change gradually or in a steady progression. In moving from the source to the target, certain fundamental features either remain constant or vary in a stable and predictable way. The plausibility of this assumption of continuity and transformation has a direct bearing on the cogency of the analogical argument (Bartha 2010, p. 224). A classic example is Darwin's theory of evolution (Bartha 2010, p. 224):

> Example 4 (Artificial and natural selection). Darwin's famous analogical argument depends upon the idea that if breeding can produce noticeable variation in a few generations, then evolution through natural selection can account for great diversity over a very long time period. Again, the concept of scale plays a major part in the argument.

Bartha notes that the invariance underlying parametric analogies can often be formally expressed as:

$Y = F(X)$ where $X = (X_1, \ldots, X_n)$.

In this formulation, X represents different time spans, F represents a series of biological processes such as breeding, and Y denotes the resulting biological changes over those time spans. Because X is assumed to vary continuously, Y is likewise expected to change in a continuous manner. On the basis of this invariance, Darwin projected the outcome of Y over an extreme time span, namely great diversity. In this way, the formula $Y = F(X)$ once again functions as a premise in the analogical argument, supporting the conclusion about "great diversity" in the target domain.

As the foregoing discussion shows, in each of the three types of generalization identified by Bartha, generalization appears to serve the same functional role: it operates as part of the premise chain that

underwrites the analogical conclusion. This observation prompts an important question: why, then, does Bartha treat generalization as the ultimate conclusion of an analogical argument? Moreover, why should the cogency of such an argument be evaluated, at least in part, by its potential for generalization?

In our view, what Bartha describes as the ultimate aim of an analogical argument should not be understood as its final practical goal. Rather, it refers to a new, generalized understanding that we cognitively form about the analogues. For example, when electricity and lightning are classified under a kind defined by twelve shared features, that kind serves as a generalization supporting the relevant similarity in the analogical argument. This kind may also encompass other shared features not yet discovered, such as the property of "being attracted to pointed objects". Once we conclude that lightning shares this property, the conclusion functions both as a projection based on the existing shared features and as a contribution to the overall similarity between the analogues. It thereby extends the scope of the generalization. Intuitively, the analogical conclusion itself can be seen as a further similarity between the analogues, redefining and extending the original generalization that is grounded in known similarities.

For this reason, we suggest that it is more accurate to view generalization not as the final conclusion of an analogical argument but as a derivative outcome. Not all analogical arguments aim to classify the analogues under a common kind; in most cases, the primary goal is simply to infer a new proposition within the target domain. Nevertheless, this new proposition can itself be understood as a further similarity between the analogues, an extended generalization that builds upon and enlarges the existing generalization formed by their prior shared features.

Therefore, in addition to grounding similarity and relevance within analogical arguments, generalization can also serve as a derivative outcome of the reasoning process. In this sense, it is a key component of analogical argument. The specific form of an

analogical generalization can also substantially influence how such arguments are evaluated. We therefore propose a unified definition and account of generalization in analogical reasoning, one that clarifies its role, explores its multiple functions, and examines its impact on the cogency of analogical arguments. Such an account would foster a deeper and more systematic understanding of generalization's role in analogical argument.

5. Analogical argument via generalizations

Based on the foregoing analysis, generalization in analogical reasoning can be seen to play three distinct roles:

1. Similarity Generalization: This involves articulating the known features that the analogs share.

2. Relevance Generalization: This extends to the features, relations, or principles that are relevant to the shared attributes within the source domain, linking the observed similarities to the conclusion being drawn.

3. Derivative Generalization: This encompasses both the established similarities and those inferred through further reasoning between the analogs.

Whether viewed as an empirical generalization of similarity, a hypothetical generalization of relevance, or a cognitive projection of the conclusion, its underlying role remains the same: to capture certain known or potential shared features between the analogs, shaped by the context of the argument. Importantly, generalization in analogical reasoning serves to articulate premises such as similarity and relevance, rather than to function as a required step in every instance of analogical inference. Even so, it can operate as a cognitive aid and offer a useful point of departure for the reconstruction and evaluation of analogical arguments.

Accordingly, generalization in analogical reasoning may be

defined as an abstraction over shared properties, relations, rules, or structures between the analogs.

To reflect this role, we propose an extension of the classical argument scheme for analogy, grounded in the function of generalization in representing key structural elements such as similarity and relevance. This extension is intended to more accurately capture the status and function of generalization within analogical reasoning. The extended components are indicated with underlining:

1. Major Premise: Generally, case C_1 is similar to case C_2 under the generalization G_1.
2. Relevant Similarity Premise: The similarity between C_1 and C_2 observed so far is relevant to the further proposition A that is in question under the generalization G_2.
3. Minor Premise: Proposition A is true (false) in case C_1.
4. Conclusion: Proposition A is true (false) in case C_2.

In this scheme, generalization G_1 corresponds to similarity generalization, while generalization G_2 corresponds to relevance generalization. Notably, generalization does not introduce any new structural element into the original argument scheme. Instead, it offers an explicit representation of similarity and relevance within analogical reasoning. This explicitness allows for a more precise assessment of how these components support the argument's conclusion.

On the other hand, the explicit formulation of generalizations G_1 and G_2 also enables the modeling and objective analysis of similarity in analogical reasoning, including context-sensitive approaches to similarity modeling and evaluation.

We begin by proposing that the construction of the similarity generalization G_1 can be described as follows:

1. [Premise] In general, cases C_1 and C_2 each exhibit a set of features.
2. Through comparison, we observe that the two cases share

features $P_1, P_2, \ldots, P_n$, exhibit conflicting features $O_1, O_2, \ldots, O_n$, and possess non-conflicting but distinct features: $S_1, S_2, \ldots, S_n$ for C_1, and $T_1, T_2, \ldots, T_n$ for C_2.

3. [Premise] Within the current argumentative context D, a subset of the shared features, $P_i, P_{i+1}, \ldots, P_{i+n}$, is particularly relevant.

4. Therefore, we formulate the similarity generalization G_1: Cases C_1 and C_2 both possess the features $P_i, P_{i+1}, \ldots, P_{i+n}$.

It can be seen that the known features of cases C_1 and C_2, along with the current argumentative context D, serve as the preconditions for generating the similarity generalization G_1. Intuitively, comparison of the two cases allows us to classify their features into three types: shared features, conflicting features, and non-conflicting but distinct features. Among these, the shared features form the core premise of the analogical argument, while the conflicting and distinct features play a central role in standard critical questions regarding the argument's cogency. Crucially, the subset of shared features deemed relevant will vary with the argumentative context D. As such, different contexts may yield different formulations of G_1, reflecting the context-sensitivity inherent in analogical reasoning.

Consider Example 1 discussed in Section 2. In comparing the solar system with the Rutherford atom, several shared features can be identified, such as mass relationships, gravitational interactions, and spatial distance relations. At the same time, the two systems also display conflicting features, such as observability, and differ in various respects, including their constituent elements and absolute scale. Among these, features like mass relationships, motion patterns, and distance relations are treated as relevant shared features in the context of the analogy. Clearly, these are not the only features the two systems share. For example, they also have similar shapes. However, since shape is not relevant to the argumentative context focused on circular motion, it is excluded from the set of considered similarities.

As for the construction of the relevance generalization G_2, we propose the following model:

1. [Premise] Within the current argumentative context D, feature A is the focus of inquiry, and it is known that proposition $A(x)$ [4]is true (false) in case C_1.

2. [Premise] In case C_1, there exists some form of association between the shared features $P_i, P_{i+1}, \ldots, P_{i+n}$, as represented in the similarity generalization G_1, and the target feature A. Moreover, A originates from the set of non-conflicting but distinct features $S_1, S_2, \ldots, S_n$.

3. Therefore, we derive the relevance generalization G_2: Assume that cases C_1 and C_2 both exhibit an association between the shared features $P_i, P_{i+1}, \ldots, P_{i+n}$ and the target feature A.

It can be seen that the current argumentative context's focus on the target feature A, along with the previously established similarity generalization G_1, forms the basis for constructing the relevance generalization G_2. With respect to Premise 1, the target feature A becomes the focus of the argument only if it is relevant within the context and the truth value of the proposition $A(x)$ in case C_1 is known. As for Premise 2, the target feature A, insofar as it is associated with the shared features, must belong to the set of non-conflicting but distinct features between C_1 and C_2, since it is neither part of the shared feature set nor in contradiction with any known features of C_2. The construction of the relevance generalization can thus be understood as an extension of the known association in C_1 into a new, potential generalization. However, because it remains uncertain whether the same association holds in C_2, this extension is necessarily hypothetical.

Returning to Example 1 in Section 2, since the focus lies on the

[4] $A(x)$ denotes the proposition that the object x possesses that feature A. Here, A is treated as a predicate (feature), and $A(x)$ asserts that this feature is exhibited in a particular case (e.g., C_1) within the current argumentative context D.

revolves-around motion of planets in the solar system, we consider whether features such as distance relations and mass relations, which are shared between the solar system and the Rutherford atom, are associated with this motion. Once such an association is identified in the solar system, it becomes possible to hypothesize that a similar association might also hold in the atomic model. However, this remains a hypothesis rather than an established empirical fact. Indeed, subsequent scientific developments and experimental testing eventually showed that the hypothesis does not hold. Nonetheless, within the argumentative context D, and given the information available at the time, the hypothesis had not yet been falsified and was therefore provisionally acceptable.

On this basis, a complete generalization-based scheme for analogical argument can be constructed:

1 Major Premise: Within the current argumentative context D, case C_1 is similar to case C_2 under the generalization G_1.

1.1 [Premise] In general, cases C_1 and C_2 each exhibit a set of features.

1.2 Through comparison, we observe that the two cases share features $P_1, P_2, \dots, P_n$, exhibit conflicting features $O_1, O_2, \dots, O_n$, and possess non-conflicting but distinct features: $S_1, S_2, \dots, S_n$ for C_1, and $T_1, T_2, \dots, T_n$ for C_2.

1.3 [Premise] Within the current argumentative context D, a subset of the shared features, $P_i, P_{i+1}, \dots, P_{i+n}$, is particularly relevant.

1.4 Therefore, we formulate the similarity generalization G_1: Cases C_1 and C_2 both possess the features $P_i, P_{i+1}, \dots, P_{i+n}$.

2 Relevant Similarity Premise: The similarity between C_1 and C_2 observed so far is relevant to the further proposition $A(x)$ that is in question under the generalization G_2.

2.1 [Minor Premise] Within the current argumentative

context D, feature A is the focus of inquiry, and it is known that proposition $A(x)$ is true (false) in case C_1.

2.2 [Premise] In case C_1, there exists some form of association between the shared features $P_i, P_{i+1}, \ldots, P_{i+n}$, as represented in the similarity generalization G_1, and the target feature A. Moreover, A originates from the set of non-conflicting but distinct features $S_1, S_2, \ldots, S_n$.

2.3 Therefore, we derive the relevance generalization G_2: Assume that cases C_1 and C_2 both exhibit an association between the shared features $P_i, P_{i+1}, \ldots, P_{i+n}$ and the target feature A.

3 Conclusion: Proposition $A(x)$ is true (false) in case C_2.

3.1 Based on the similarity generalization G_1 and the relevance generalization G_2, it may be hypothesized that cases C_1 and C_2 share the same truth value with respect to proposition $A(x)$.

3.2 [Premise] In case C_2, the truth value of proposition $A(x)$ does not conflict with the propositions corresponding to its known features $T_1, T_2, \ldots, T_n$.

The conclusion is derived from the similarity generalization G_1 and the relevance generalization G_2 established in the premises. Moreover, this conclusion suggests a further generalization, namely that cases C_1 and C_2 share the same truth value with respect to proposition $A(x)$. Since the conclusion is hypothetical in nature, it must be tested against existing propositions in case C_2 to determine whether any contradiction arises. Such testing strengthens the plausibility[5] of

[5] The notion of "plausibility", as it applies to a claim or hypothesis, serves as a key criterion in the evaluation of arguments. While "cogency" concerns the overall strength and coherence of an argument, "plausibility" focuses more specifically on the credibility of particular assumptions, premises, explanations, or claims within it. As Govier defines it, plausibility refers to "reasonableness or likelihood of being true, judged by consistency with relevant common knowledge and

the conclusion. If a contradiction is found, it indicates that the hypothesis underlying the conclusion, or even the assumed relevance generalization G_2, is flawed, and that the relevance observed in case C_1 should not be projected onto case C_2.

To illustrate, let us return to Example 1 in Section 2. Drawing on shared properties between the solar system and the atom, such as mass relations, spatial distances, and gravitational interactions, and on the possibility that these features are jointly relevant to the motion observed in the source domain (e.g., $revolves\_around(planet, sun)$), it is inferred that a similar type of motion might apply to atomic structure. However, it is essential to assess whether this motion is consistent with what is known about atoms, for instance the actual trajectories of electrons. At the time, the behavior of electrons remained poorly understood, and no existing knowledge ruled out the possibility that electrons could revolve around the nucleus. Accordingly, the conclusion of this analogical argument constituted a plausible hypothesis, one that warranted empirical investigation.

Based on this argument scheme, it becomes clear that both central premises in an analogical argument are fundamentally constructed through generalization. Generalization not only serves to represent the similarity and relevance premises but also provides the structural pathway for their formation. Technically, the explicit construction of these premises forms a complex argument, in which the major premise, the relevance-based similarity premise, and even the conclusion in the classical model of analogical reasoning each has its own sub-argument[6]. Within this framework, the so-called minor premise of

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scientific theory" (2010, p. 315) .

[6] It is important to note that the sub-arguments used to construct the major premise, the relevance-based similarity premise, and even the conclusion of an analogical argument are not themselves analogical arguments; rather, they constitute components of a single analogical argument. If these sub-arguments are to be classified by type, the similarity premise aligns most closely with arguments from knowledge, whose cogency depends on background understanding of the analogues and the purpose of the analogy. By contrast, the relevance premise may

the classical scheme is, in fact, a premise within the relevance-based similarity premise: only when the truth value of proposition $A(x)$ is established in the source domain can we assess whether the similarity between the source and target is relevant to feature A. Moreover, the process of generalization in analogical reasoning is context-sensitive. Whether it involves similarity or relevance, the formulation of the premises depends on the argumentative context D, which determines the selection and salience of particular features.

At the same time, the similarity generalization, the relevance generalization, and the analogical conclusion together constitute an additional line of reasoning. Specifically, the similarity generalization functions as a premise for the relevance generalization and provides the basis for its construction. In turn, the similarity and relevance generalizations jointly support the analogical conclusion. This line of reasoning defines an abstract inferential space with the following structure:

> 1.4 Similarity generalization G_1: Cases C_1 and C_2 both possess the features $P_i, P_{i+1}, \dots, P_{i+n}$.
>
> 2.3 Relevance generalization G_2: Assume that cases C_1 and C_2 both exhibit an association between the shared features $P_i, P_{i+1}, \dots, P_{i+n}$ and the target feature A.
>
> 3.1 [Conclusion]: Cases C_1 and C_2 share the same truth value with respect to proposition $A(x)$.

This abstract inferential space corresponds to what Walton describes

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take different argumentative forms, depending on the nature of the association observed in case C_1 between the shared features $P_i, P_{i+1}, \dots, P_{i+n}$ (as captured by generalization G_1) and the target feature A. If this association is deductive, the premise forms a deductive argument; if inductive, it may be treated as an inductive argument; and if the association reflects a correlation-to-cause pattern, it may be viewed as a causal argument. Thus, the cogency of the relevance generalization depends on both the form of premise [2.2] and its underlying credibility. As for the conclusion, its cogency depends not only on support from the preceding premises but also on a consistency check to ensure cognitive acceptability in non-deductive contexts.

as a story scheme, a pattern involving a sequence of shared abstract features and the consequences that may follow from them.

This framework reveals the dynamic interaction between analogy and abstraction. By identifying similarities, analogical reasoning extracts shared properties from the cases under comparison, forming an initial abstract concept, the similarity generalization. This is followed by a further abstraction, the relevance generalization, which extends empirical knowledge from the source domain to establish a presumed connection to the target property. These two abstract generalizations then jointly serve as the premises for the analogical conclusion. Thus, analogical argument inherently involves the generation of abstract concepts, which in turn facilitate the derivation of the analogical conclusion. This dynamic aligns with findings in cognitive science, where experimental studies have demonstrated a close relationship between analogy and abstraction (Gentner and Hoyos 2017; Kotovsky and Gentner 1996).

Therefore, we argue that generalization plays a pivotal role in analogical reasoning. On the one hand, it explicitly represents the premises of similarity and relevance; on the other, it clarifies the process by which these premises are constructed. This dual function offers a more fine-grained and transparent framework for evaluating analogical arguments, enabling the formulation of more precise and targeted critical questions. We develop this point in greater detail in the sections that follow.

6. The specificity of analogical generalization and its implications

Before turning to a critical evaluation of analogical generalization, it is necessary to clarify several foundational questions:

1. Does the construction of analogical generalization reduce analogical argument to a form of deductive reasoning or inductive generalization?

2. In what respects is analogical generalization distinct from deductive rules and inductive generalizations?

3. What implications do these distinctive features of analogical generalization have for understanding analogical argument as a mode of reasoning?

The question of whether analogical argument constitutes a *sui generis* form of reasoning has long been a topic of sustained debate within informal logic. Some scholars maintain that analogical arguments can ultimately be reduced to either deductive or inductive reasoning. The deductive view holds that the logical force of an analogical conclusion does not stem from similarity per se, but from an implicitly assumed "hidden generalization" (Beardsley 1975, pp. 113–14) or "principled proposition" (Waller 2001) that is already accepted or known. By contrast, proponents of the inductive view argue that analogical arguments involve an implicit general principle whose credibility is probabilistically reinforced by the accumulation of analogous cases in the source domain (Botting 2012, 2017).

Other scholars, however, maintain that analogical argument constitutes a *sui generis* form of reasoning, one with a distinctive logical structure that cannot be reduced to either deduction or induction. Barker (1989) and Guarini (2004) argue that the "principle" invoked in analogical reasoning is not pre-established or known in advance, but is instead constructed progressively during the course of reasoning. Guarini further observes that analogical arguments admit of degrees of strength, a feature that deductive reasoning cannot accommodate (2004). Juthe likewise contends that analogical arguments do not rely on statistical generality, nor do they derive from formal validity (2005, 2020). Rather, they represent a distinct type of reasoning. According to Juthe (2020), the essence of analogical argument lies in the comparison of similarities, not in the application of a general principle. Moreover, he emphasizes that similarity and relevance are not independent components, but are logically intertwined within the structure of analogical reasoning. Liao (2024) adds that the

logical force of the similarity proposition derives from its role in constructing the principle itself. Accordingly, analogical argument cannot be reduced to a purely principle-driven form of reasoning.

A central point of contention in the debate over the *sui generis* status of analogical argument concerns the so-called principle statement. Does analogical reasoning presuppose a general principle? And is this principle the sole logical basis for the justificatory force of the argument? These two questions lie at the heart of any attempt to defend the uniqueness of analogical reasoning. Against this backdrop, a further challenge emerges: Does the presence of analogical generalization, an apparently general statement that plays a key structural role in analogical argument, undermine the claim that analogy constitutes a distinct mode of reasoning?

In our view, the answer is negative. Analogical generalization exhibits distinctive features that differentiate it from the universal principles of deductive reasoning and the statistical generalizations of inductive inference. Far from undermining the uniqueness of analogical argument, analogical generalization, by constructing and representing similarity and relevance, serves to clarify and reinforce the claim that analogy constitutes a *sui generis* mode of reasoning.

First, we contend that the most salient feature distinguishing analogical generalization from the universal principles of deductive reasoning is its empirical and hypothetical character. Whereas deductive principles typically function as a priori rules, similarity generalizations in analogical arguments are empirical descriptions of observed phenomena, and relevance generalizations are hypothetical conjectures about possible rule-like relations. These generalizations necessarily rest on empirical premises that cannot be disregarded without undermining the argument itself.

As the preceding discussion suggests, what is often termed the "principle statement" in analogical argument typically denotes a presumed connection between the similarity premise and the target conclusion, which this paper identifies as the relevance generalization (G_2). In the generalization-based scheme of analogical argument,

however, the construction of a relevance generalization depends on an antecedent similarity generalization (G_1). On the one hand, only by first identifying the similarities between the source and target can one determine the form of the relevance generalization on which the analogical inference rests. On the other hand, the content of a relevance generalization necessarily incorporates the shared features captured in the similarity generalization; the two are therefore conceptually nested. As Juthe aptly observes, similarity and relevance are not independent logical components within analogical reasoning (2020). The construction of a relevance generalization necessarily presupposes, and is structurally grounded in, a similarity generalization.

Moreover, the hypothetical nature of a relevance generalization shows that it is not an a priori principle but a conjecture constructed from observed correlations in the source domain and the identified similarities between the analogues. In this sense, a relevance generalization can also be regarded as a sub-conclusion within the analogical argument, one of its intermediate inferential outcomes. At the same time, because it functions as a hypothesis rather than a fixed principle, a relevance generalization cannot serve as a fully dependable premise from which a compelling conclusion could be derived in isolation.

Consider Example 2. Franklin's analogy between lightning and electricity rested on twelve rich, distinctive, and concentrated shared features. From these, he inferred that lightning, like electricity, possesses the property of being attracted to pointed objects. At the time, no established causal link was known between these twelve shared features and the property of "being attracted to points." What had been observed, however, was that in phenomena involving electrical currents, this property frequently co-occurred with some subset of those twelve features, an empirical pattern that, in Franklin's experience, suggested relevance. On this basis, his analogical reasoning proceeded by hypothesizing a causal connection between the known shared features of lightning and electricity and the target property,

thereby yielding the analogical conclusion.

This example illustrates that, in analogical argument, the connection between shared features and the target conclusion is not typically known in advance; it is instead hypothesized and constructed in the course of the analogical process itself and may even form part of the analogical conclusion requiring further empirical verification. Should experimental evidence confirm that certain features among the twelve shared ones are causally related to the property of being attracted to points, the hypothetical relevance generalization would gain empirical support, thereby substantially increasing the plausibility of the analogical conclusion.

In Example 1, the similarity generalization between the solar system and the Rutherford atom rests on their shared properties of mass relations, spatial distances, and force interactions. The corresponding relevance generalization posits a presumed connection between these properties and a resulting pattern of motion. While the shared features in the similarity generalization are grounded in empirical observation, the relevance generalization, namely that similar mass, distance, and force relations will yield analogous orbital motion, is a hypothesis rather than an established principle. In the solar system, the mass distribution, spatial arrangement, and gravitational attraction between the sun and planets produce stable orbital motion. However, there is no empirical basis for claiming that any system with similar parameters will necessarily exhibit the same motion. Later research revealed a fundamental difference between gravitational and Coulomb forces: gravity involves negligible energy dissipation, whereas the Coulomb force, being electromagnetic, causes continuous energy loss when electrons accelerate. Consequently, gravitational attraction can sustain stable orbits, but the Coulomb force cannot maintain a stable electron trajectory. Thus, the hypothesized relevance generalization in this analogy proved false, significantly undermining the cogency of the analogical conclusion. Although gravity and the Coulomb force share some formal similarities, their differing energy dissipation properties make them disanalogous

in the specific context of motion-based reasoning. Under this argumentative context, they cannot be treated as genuinely shared features, and the proposed relevance generalization fails.

Second, another defining feature of analogical generalization is its context-sensitivity. The selection, formulation, and evaluation of such generalizations are determined by the specific argumentative context and can shift as background knowledge or conceptual understanding develops. Unlike inductive generalizations, which typically gain cogency through the accumulation of supporting cases, an analogical generalization derives its strength less from the number of confirming instances and more from its contextual relevance. Its plausibility depends on whether the identified similarities are salient and significant within the given domain of discourse, rather than on statistical frequency.

We begin by arguing that the cogency of an analogical generalization does not, in fact, hinge on the number of similar cases. As noted earlier, the general principle often taken to underlie analogical arguments typically aligns with what we have called a relevance generalization. This prompts an important question: which factors chiefly determine the cogency of such a generalization?

As our analysis of Example 1 shows, the relationship between mass, distance, and force can produce the revolving motion of a smaller object around a larger one. This link is evident in many physical phenomena, for example the Earth orbiting the Sun, the Moon orbiting the Earth, and artificial satellites orbiting the Earth. Such cases offer empirical support for the proposed relevance generalization. What they reinforce, however, is not the analogical conclusion itself, but the plausibility of the premise on which that generalization rests, specifically the credibility of premise [2.2], which posits a connection between the shared features and the target property within the source domain.

As shown in the earlier analysis, the cogency of the relevance generalization in the analogy between the solar system and the atom was greatly reduced by the discovery of key differences in the types

of forces at work in each system, differences that directly undermined the plausibility of the proposed generalization. This indicates that strengthening a relevance generalization depends less on adding more source-domain cases than on identifying and reducing differences that are irrelevant to the specific argumentative aim. In other words, what matters is not the number of source cases, but their quality, specifically the degree to which they share features that are salient in the current argumentative context. This is why similarity and relevance in analogical argument are inseparable: the assessment of a relevance generalization necessarily relies on the underlying similarity generalization.

Moreover, we stress that what matters is the similarity of source-domain cases in terms of the features salient to the current argumentative context. This implies that the cogency of an analogical generalization must be judged within a specific context of reasoning. In the generalization-based scheme of analogical argument, it is clear that both similarity generalization and relevance generalization are bounded by the set of features considered relevant in context D, as reflected in premises [1.3] and [2.1].

A well-known example of analogical reasoning is the "houseboat case" (Schauer 2014) (Example 5). Fane Lozman, a resident of Riviera Beach, owned a "floating home" (houseboat) and sued the city to prevent it from seizing the structure. The city, which owned and operated the marina where Lozman docked, sought removal on the grounds that he had failed to pay docking fees. Both the district court and the Eleventh Circuit Court of Appeals ruled for the city. However, in a 7–2 decision, the U.S. Supreme Court ultimately ruled in Lozman's favor.

In this analogical dispute, the city and the lower courts likened Lozman's houseboat to a ship. They argued that, because it was moored on water and shared the basic structural features of a vessel, it should be governed by maritime law and subject to governmental authority. The Supreme Court, by contrast, held that the closer analogy was to a residence. Unlike a ship, the structure had no engine or

propulsion system, remained permanently moored, and relied on land-based utilities. It was therefore not functionally suited for maritime transportation and did not fall within maritime jurisdiction.

In legal adjudication, functional characteristics typically carry more weight than superficial features. From the Supreme Court's perspective, the relevant consideration was that Lozman's houseboat lacked the capacity for maritime transportation and was functionally used as a residence. Although it shared many physical similarities with conventional vessels, those features were not salient in the legal reasoning context at issue. Consequently, the relevance generalization assumed by the lower courts, namely that "objects with the features of a ship fall under maritime jurisdiction", did not hold in this context, even though ships themselves remain subject to maritime law.

In architectural design, however, constructing a houseboat requires attention to many features associated with ships. It must be able to float on water, and its drainage, electrical, and structural systems often need to be designed with reference to standard maritime vessels. For an architect or designer, therefore, drawing an analogy between a houseboat and a ship, and using it to guide design decisions, is entirely reasonable.

Thus, both similarity generalization and relevance generalization are formulated and assessed within the constraints of the chosen argumentative context. The cogency of a relevance generalization, often expressed as a principle-like statement, does not depend on the number of supporting source-domain cases. Rather, it turns on the reasonableness of treating the shared features between the source and target as relevant in the current argumentative context, that is, on the cogency of the corresponding similarity generalization. This again confirms the inseparability and mutual dependence of similarity generalization and relevance generalization in analogical reasoning.

It is therefore clear that the presence of an analogical generalization does not reduce an analogical argument to either deductive or

inductive reasoning. Owing to its empirical grounding, hypothetical character, and context sensitivity, analogical generalization is fundamentally distinct from both universal deductive rules and inductive generalizations. Analogical argument is a structurally and functionally distinctive form of reasoning.

But does this special kind of generalization cease to be a generalization in any meaningful sense? We contend that it does not. As shown in our earlier analysis, certain causal connections, such as those between specific shared features among the twelve identified and the property of being attracted to points, can still constitute general knowledge.

Traditional inductive generalization constructs knowledge by deriving general principles from a large set of data samples that share common attributes, facts, or patterns (Gust et al. 2007). Because of the diversity and quantity of such samples, the resulting generalizations are often regarded as broadly applicable and largely independent of specific contexts. In real-world cognition, however, humans do not always require many examples to acquire new knowledge. Through analogical reasoning, people detect structural similarities, relational correspondences, and role alignments between individual cases. Although seldom universally applicable, this form of analogical generalization still captures localized regularities and demonstrates the human capacity for abstraction and knowledge transfer.

Analogical generalization is not outside the scope of generalization; rather, it is a context-sensitive, tendency-guided form. As Ohkawa et al. note, a person can acquire general knowledge from a single example precisely because of a strong tendency to generalize in domain-specific ways (1992). Although it lacks the universality of deductive rules or inductive generalizations, analogical generalization nonetheless retains both cognitive legitimacy and practical significance.

Moreover, the empirical, hypothetical, and context-sensitive nature of analogical generalization makes analogical argument more uncertain and defeasible than deductive or inductive reasoning,

introducing a degree of argumentative risk.

The defeasible nature of analogical argument has been widely noted (Freeman 2013; Juthe 2015; Walton et al. 2008). Walton, in particular, stresses that analogical argument is a defeasible form of reasoning (2008, p. 61). Its strength lies not in providing an unassailable deductive inference, but in its capacity to offer a contextually reasonable justification. Although analogical arguments often exhibit a logical structure, their conclusions can be weakened or overturned by showing irrelevance, significant disanalogies, or counterexamples (Walton et al. 2008, pp. 61–62). For this reason, the cogency of an analogical argument is best assessed not solely by its logical form, but through a set of critical questions.

Clearly, the hypothetical nature of relevance generalization is a key source of the defeasibility of analogical argument. As a hypothesis or conjecture, it is open to verification, challenge, or refutation. As shown in our earlier analysis of Example 1, however, defeasibility in analogical reasoning is not confined to relevance generalization; even empirical similarity generalizations can be revoked. For instance, the judgment that gravity and the Coulomb force constitute a shared feature was later abandoned in light of new scientific findings. This defeasibility of similarity generalization stems from its context sensitivity: as the argumentative context shifts, the shared features identified between the analogues may also change. Thus, the defeasibility of analogical argument arises from the combined effect of context-sensitive similarity generalization and hypothetical relevance generalization.

In addition, the empirical, hypothetical, and context-sensitive nature of analogical generalization makes it especially susceptible to faulty or unwarranted generalizations, thereby weakening the cogency of the analogical argument. We identify three common types:

1. False generalization: arising from neglecting critical differences between the analogues.
2. Empty generalization: resulting from overcomplicating

the generalization process in an effort to force alignment between source and target.

3. Limited generalization: stemming from incomplete or insufficient information about the analogues.

False generalization is particularly common in analogical reasoning and often arises from neglecting contextually relevant information, specifically from overlooking critical differences between the analogues that are salient in the argumentative context. As illustrated in Example 5, the houseboat case, the similarity generalization drawn by the city and the lower courts between Lozman's houseboat and a conventional ship was a false generalization. It failed to account for the conditions required for applying maritime law and ignored key functional differences between the houseboat and a ship, differences that were crucial in the legal context of the dispute.

Empty generalizations are also common in analogical reasoning, especially in highly structured or formalized arguments. Often, in an effort to align two analogues, the reasoner introduces numerous substitution rules to construct generalizations between them. For example, one may artificially add or decompose components of a formula solely to force structural alignment. Any generalization, however, is generated through information discard. In similarity generalization, constructing similarity between distinct objects necessarily involves disregarding features irrelevant in the argumentative context. Likewise, in relevance generalization, certain contextual conditions or background premises in the source domain are deliberately set aside to apply a rule to the target domain. While such selective omission can be legitimate, problems arise when generalization is pursued for its own sake, resulting in excessive information loss, including features that are contextually important to the argument. In such cases, the generalization may not be outright false, but it fails to contribute meaningfully to the analogical reasoning. This is why the HDTP framework places explicit constraints on the complexity of generalization construction.

The third type, limited generalization, should not be regarded as faulty or illegitimate. It arises from the reasoner's limited knowledge of the analogues, such as an incomplete understanding of the target domain or uncertainty about the scope of applicability of the relevance generalization. This does not mean that the analogical argument is inherently flawed. Some analogical conclusions may later be shown to be incorrect through empirical investigation, yet still be reasonable given the background knowledge available at the time. Such arguments can serve as simplified models for explaining phenomena in the target domain. A well-known example is the analogy between the Rutherford atomic model and the solar system, which, despite its scientific limitations, continues to play an important explanatory role in textbooks. In this sense, a limited generalization may become less tenable as cognitive understanding advances but can still function effectively within a constrained epistemic context.

It is thus evident that constructing an analogical generalization does not reduce an analogical argument to either deductive or inductive reasoning. Analogical argument remains a *sui generis* form of reasoning. Unlike the a priori certainty of deductive rules, analogical generalizations are empirical, with relevance generalizations often emerging as hypothetical conjectures developed during the course of reasoning. Unlike the universality and sample-dependence of inductive generalizations, they are highly context-sensitive, emphasizing relevance within a specific argumentative setting. These features help explain why analogical reasoning is generally more uncertain and defeasible than deductive or inductive reasoning. Moreover, analogical generalization is especially susceptible to problematic forms, including false, empty, and limited generalizations.

7. Evaluation of analogical arguments grounded in generalization

As discussed in Section 5, generalization plays a central role in the

structure of analogical arguments, providing a way to model both similarity and relevance. Grounding the evaluation of such arguments in analogical generalization can offer a more precise and transparent basis for assessing their cogency. Building on Walton et al.'s method of evaluating analogical reasoning through critical questions, we propose a set of questions specifically framed in terms of analogical generalization.

First, for the similarity generalization (G_1), the key issue is whether the shared features $P_i, P_{i+1}, \ldots, P_{i+n}$ are relevant to the current argumentative context D. This critical question highlights the context-sensitivity of the similarity generalization, namely whether the identified features are salient in the given context. Only when these features are both relevant and significant within context D can the subsequent relevance generalization and the analogical conclusion be considered cogent.

For example, in analogical arguments intended for emotional appeal, the relevant shared features should concern emotional resonance. By contrast, in analogical arguments directed toward scientific discovery, the relevant features should involve scientific terminology and observable phenomena. More specifically, as shown in Example 1, if the purpose of the analogy between the solar system and the atom is to explain the motion of electrons, then any features known to be irrelevant to motion should not count as relevant shared features in this argumentative context.

Another critical question is whether there are conflicting features $O_1, O_2, \ldots, O_n$ within context D that weaken the similarity generalization. This question addresses the risk of false generalization. As noted in the previous section, the distinctive character of analogical generalization makes it especially vulnerable to unwarranted extensions, particularly those that result from ignoring contextually significant differences between the analogues. When a conflicting feature is present in context D, a key property holds for one analogue but not the other, thereby undermining the plausibility of treating them as analogous in that context.

For example, we initially treated gravity and the Coulomb force as sharing the general property of being forces, and thus as equivalent for purposes of similarity generalization. When the context shifted to motion-related behavior, however, a conflicting feature became salient: gravity is associated with minimal energy dissipation, whereas the Coulomb force entails substantial energy loss. This conflict weakens the analogy between the two forces in the given context, thereby undermining the similarity generalization.

Then, for the relevance generalization (G_2), several critical questions arise. The first two are: within the current argumentative context D, can the truth value of proposition $A(x)$ be reliably determined in case C_1, and in context C_1, is there sufficient justification for the association between the shared features $P_i, P_{i+1}, \dots, P_{i+n}$ and feature A? These questions assess the cogency of premises [2.1] and [2.2] and serve as safeguards against overemphasizing the target domain while neglecting the plausibility of information drawn from the source domain.

Another critical question is whether there are non-conflicting but divergent features $S_1, S_2, \dots, S_n$ and $T_1, T_2, \dots, T_n$ that are sufficiently significant within context D to undermine the relevance generalization. This question addresses what the previous section identified as the problem of empty generalization. In seeking to emphasize structural similarity between analogues, arguers often introduce too many transformation rules to produce a forced alignment, while neglecting whether such alignment is genuinely warranted by the argumentative context. The features lost in this process of artificial alignment are typically the non-conflicting yet divergent features noted in the preceding question. These features, however, may carry substantial contextual weight and play a crucial role in determining the plausibility of the relevance generalization.

For example, suppose we observe that centrifugal motion in the solar system depends on mass distribution, spatial distance, gravitational force, and minimal energy dissipation. At the time, however, the energy dissipation of atoms was poorly understood. In this case,

minimal energy dissipation, though not in direct conflict with features of the atomic system, constitutes a divergent feature of the source domain. Because it is relevant to the context of motion, the absence or neglect of this feature reduces confidence in generalizing the source-domain relation and thereby undermines the plausibility of the relevance generalization.

We must also ask whether there are conflicting features $O_1, O_2, \dots, O_n$ within context D that undermine the relevance generalization. This question likewise concerns the problem of false generalization. Since the relevance generalization rests on the foundation of the similarity generalization, any weakening of the latter correspondingly undermines the former.

Finally, the last critical question is whether proposition $A(x)$ conflict with the propositions corresponding to all known features of C_2, including $P_1, P_2, \dots, P_i, \neg O_1, \neg O_2, \dots, \neg O_n$, and $T_1, T_2, \dots, T_n$. This question functions as a safeguard for the analogical conclusion. If proposition $A(x)$ is in conflict with the propositions corresponding to the known features of C_2, this suggests that the hypothesized relevance generalization is untenable, and that the attempted extension of source-domain relevance to the target domain is unjustified.

To summarize, the critical questions corresponding to the generalization-based scheme of analogical argument are as follows:

- CQ1': Are the shared features $P_i, P_{i+1}, \dots, P_{i+n}$ relevant to the current argumentative context D?
- CQ2': Are there any conflicting features $O_1, O_2, \dots, O_n$ within context D that undermine the similarity generalization and relevance generalization?
- CQ3': Within the current argumentative context D, can the truth value of proposition $A(x)$ be reliably determined in case C_1?
- CQ4': In context C_1, is there sufficient justification for the association between the shared features $P_i, P_{i+1}, \dots, P_{i+n}$ and

feature A?

- CQ5': Are there any non-conflicting but divergent features $S_1, S_2, \ldots, S_n$ and $T_1, T_2, \ldots, T_n$ that are sufficiently significant within context D to undermine the relevance generalization?

- CQ6': Does proposition $A(x)$ conflict with the propositions corresponding to all known features of C_2, including $P_1, P_2, \ldots, P_i$, $\neg O_1, \neg O_2, \ldots, \neg O_n$, and $T_1, T_2, \ldots, T_n$?

As we can see, CQ1'–2' concern the evaluation of the similarity generalization, while CQ2'–6' address the evaluation of the relevance generalization. Because the similarity generalization is empirical in nature, it invites scrutiny mainly with respect to its contextual appropriateness and whether it adequately reflects the perceived identity between the analogues in the given context. By contrast, the relevance generalization is hypothetical in nature and therefore becomes the central focus of critical assessment. CQ3'–4' reconsider the underlying premises that support the construction of the relevance generalization, whereas CQ2' and CQ5'–6' examine the cogency of extending source-domain relevance to the target domain, in other words, the plausibility of the hypothetical projection.

At the same time, compared with Walton's classical critical questions, the critical questions developed here, grounded in analogical generalization, provide greater operational clarity. CQ3', for instance, corresponds directly to Walton's CQ1, which addresses the plausibility of the minor premise in an analogical argument. Yet if the aim is to evaluate the truth of that premise, then, in principle, all premises in the reasoning process should be examined. This is why CQ4' is introduced: it probes whether a substantive connection actually holds between the shared features and the target proposition within the source domain. In doing so, it helps ensure that the relevance generalization rests on empirically or theoretically credible support.

Additionally, CQ1'–2' correspond to Walton's classic CQ2,

which asks whether the compared cases are genuinely similar in the given context; likewise, CQ2' and CQ5' align with Walton's CQ3, which considers whether dissimilarities undermine the analogy. Yet CQ2 and CQ3 in the original framework partially overlap and lack clear analytical boundaries. For example, CQ2 invites the evaluator to assess whether the cases are similar but offers little guidance on how similarity should be determined or which dimensions matter. Similarly, CQ3 leaves unspecified what kinds of differences warrant concern, whether attention should focus only on directly conflicting features or also on non-conflicting divergences. Should all differences be treated equally, or should they be weighed in light of context? More importantly, how should these differences be understood in argumentative terms? Do they primarily weaken perceived similarity, or do they undercut projected relevance? These questions remain unanswered in the classic formulation. By contrast, CQ1'–2' and CQ5' draw clear distinctions between types of differences and explicitly connect their evaluation to both the argumentative context and the structure of analogical generalization.

As for CQ4 in Walton's classic set, namely whether there exists another case C_3 that is also similar to C_1 except that $A(x)$ is false (true) in C_3, we suggest that this question in fact conflates two distinct concerns: (1) whether C_1 contains additional features (i.e., those shared with C_3) that might support the negation of $A(x)$; and (2) whether the same similarity generalization (G_1) might support a different proposition $B(x)$ in a different case C_3.

The first concern is already addressed by our CQ6', which avoids the need to search for an actual counter-case C_3 by instead examining whether the propositions corresponding to the known features of C_2 are in conflict with $A(x)$. This provides a more direct and operational means of testing the generalization. As for the second concern, we argue that it does not undermine the cogency of the original analogical argument. The existence of another conclusion $B(x)$, supported by the same similarity generalization G_1 in a different context, does not invalidate the connection between G_1 and $A(x)$ in the

current case. A single similarity generalization may well support multiple, non-conflicting propositions across distinct contexts.

Finally, we incorporate contextual considerations into the critical questions. CQ1'–3' and CQ5' require attention to how the argumentative context shapes the plausibility of both the similarity and relevance generalizations. Consequently, the evaluation of analogical arguments through these questions will vary with changes in context.

In practice, however, different uses of analogical arguments may give greater weight to some critical questions than to others, depending on their argumentative purpose. For example, clearly articulated similarity and relevance support the generation of new insights, whereas potential counterexamples become especially significant when the argument serves a justificatory or persuasive function.

In heuristic analogical arguments, the primary goal is to generate new ideas or propose novel hypotheses. As such, rather than emphasizing rigorous justification, these arguments focus on the kinds of analogies most conducive to stimulating thought. Accordingly, CQ1' and CQ3'–4' become central concerns. CQ1' ensures that the identified similarities are contextually relevant, thereby reducing the risk of meaningless transfers. CQ3' and CQ4' help ground the analogical projection in the source domain, minimizing the chance of producing unfounded or purely speculative hypotheses. Besides, since heuristic analogies are oriented toward possibility rather than certainty, they tend to be more tolerant of conflict and difference, even embracing challenges to existing knowledge as a way to break conventional boundaries. As a result, CQ2', CQ5', and CQ6' are relatively less critical in this context.

In contrast, justificatory or persuasive analogical arguments aim to support a standpoint, persuade others, and enhance the plausibility of the conclusion within a given reasoning context. As such, the evaluation of their cogency places relatively greater emphasis on rigor and consistency, particularly through attention to potential counterexamples. For this type of analogical reasoning, CQ2', CQ5', and CQ6', which lend themselves to the identification of

counterexamples, tend to receive heightened attention. This does not suggest a universally higher standard of cogency for justificatory or persuasive analogical arguments; rather, it reflects a different evaluative orientation, one that places more weight on internal coherence and resistance to objection compared to heuristic analogical arguments.

This demonstrates that analogical generalization is not merely a component in the construction of analogical arguments but also serves as a central anchor for evaluating their cogency. A well-constructed analogical generalization effectively forms the foundation of a strong analogical argument. Accordingly, a critical examination of both similarity and relevance generalizations provides a more structured and practical framework for assessing the reasonableness of analogical reasoning. Moreover, different types of analogical arguments may prioritize different critical questions, depending on their specific argumentative aims.

In the following section, we illustrate this generalization-based scheme of analogical argument and its evaluative framework through a concrete case study.

8. Case reconstruction and evaluation

In practice, not all components of an analogical argument are stated explicitly. It is therefore often necessary to reconstruct the argument within a specific analytical framework to clarify its underlying reasoning. We suggest that the generalization-based scheme of analogical argument provides valuable insight into how similarity and relevance are constructed, thereby enhancing the evaluation and understanding of analogical reasoning.

Accordingly, we will apply the generalization-based scheme to a detailed case analysis of the analogical argument in Example 4, namely Darwin's argumentation for evolution by natural selection, along with its supporting and opposing views. This will demonstrate how the scheme facilitates the analysis and evaluation of the

argument itself, as well as the criticisms and defenses surrounding it.

In *On the Origin of Species*, Darwin made extensive use of analogical argumentation to develop and clarify his theory of evolution (1964). One of the most well-known examples is the analogy between artificial selection and natural selection, which serves as a central argumentative tool for explaining the mechanism of evolutionary change. Darwin observed that through selective breeding, such as in pigeons, dogs, and cultivated plants, humans could substantially alter biological traits over relatively short periods, resulting in varieties that differ significantly from their wild ancestors. He argued that if deliberate human selection could accumulate changes across generations, then natural selection, operating without intention over long timescales through environmental pressures like resource competition and predation, could produce comparable evolutionary outcomes. A prominent critique of Darwin's analogical reasoning came from Alfred Russel Wallace (1889), who questioned the cogency of the analogy by pointing to crucial differences in teleological assumptions, temporal scale, and hereditary mechanisms.

To this end, we reconstruct Darwin's analogical argument between artificial selection and natural selection as follows:

1 Major Premise: Within the argumentative context concerning species transformation, artificial breeding (C_1) and natural species generation (C_2) are similar under the generalization G_1, in that both involve the shared feature of selective pressure.

1.1 [Premise] In general, both artificial breeding and natural species generation exhibit a range of features.

1.2 Through comparison, we identify the following:

- Shared features (P): selective pressure, reproduction;
- Conflicting features (O): artificial breeding vs. non-artificial processes; intentionality vs. lack of intentionality;
- Non-conflicting but distinct features (S for C_1/ T for C_2):

- C_1(Artificial breeding): trait modification, short time span, inbreeding;
- C_2 (Natural species generation): resource competition, predation;

1.3 [Premise] In the context of species transformation (D), the shared feature that is particularly salient is selective pressure.

1.4 We thus formulate the similarity generalization G_1: Artificial breeding and natural species generation both involve selective pressure.

2 Relevant Similarity Premise: The similarity in selective pressure (G_1) is relevant to the further feature A, namely trait modification, because selective pressure is commonly understood as a causal mechanism contributing to trait modification in the evolutionary process.

2.1 [Minor Premise] Within the same argumentative context, attention shifts to trait modification, which is empirically observed in artificial breeding (C_1).

2.2 [Premise] In artificial breeding, selective pressure (as identified in G_1) functions as a causal factor in the emergence of trait modification. Additionally, trait modification in C_1 co-occurs with non-conflicting but domain-specific features, such as short timescale and inbreeding.

2.3 Therefore, we derive the relevance generalization G_2: Selective pressure can be hypothesized to produce trait modification in both domains via a comparable causal mechanism.

3 Conclusion: Trait modification can also be inferred to occur in natural species generation (C_1).

3.1 Based on the similarity generalization (G_1) and the relevance generalization (G_2), it can be hypothesized that artificial

breeding and natural species generation share the same truth value with respect to the feature of trait modification.

3.2 [Premise] In the case of natural species generation, the occurrence of trait modification is not inconsistent with known features such as resource competition and predation.

To begin with, the similarity generalization G_1, which represents the similarity between artificial breeding and natural species generation, is not self-evident. Rather, it is constructed based on our understanding of the features being compared and shaped by the argumentative context. In fact, Darwin observed that humans engage in selective breeding when cultivating domestic animals, for example by preserving particular beak shapes or feather colors in pigeons, whereas in the natural world organisms are subject to environmental pressures such as resource competition and predation. While these are distinct features in artificial breeding and natural species generation, they play a common functional role: they both exert selective pressure. Moreover, selective pressure is a contextually relevant similarity in the argumentative context concerned with species transformation. This is because selective pressure is the mechanism by which advantageous variations are filtered and accumulated within a population, and such accumulation of adaptive traits constitutes the basis of trait transformation within species. The direct connection between selective pressure and the explanatory goal of the analogy makes it a key similarity in this argument. On this basis, Darwin constructs the similarity generalization: the presence of selective pressure.

With respect to the similarity generalization, we propose two critical questions, CQ1' and CQ2':

- CQ1': Is the shared feature selective pressure relevant within the argumentative context concerned with species transformation?
- CQ2': Are there any conflicting features, relevant to the

same argumentative context, that weaken the similarity and relevance generalizations?

The judgment required for CQ1' is relatively straightforward. By contrast, CQ2' has become a focal point for critics of Darwin's analogy between artificial and natural selection. Among the most well-known objections is Wallace's claim concerning the difference in intentionality. Wallace argued that there exists a significant conflicting feature between artificial breeding and natural species generation: the former involves intentional selection, while the latter proceeds unconsciously and without purpose. On this basis, he argued that selective pressure does not constitute a meaningful similarity between the two processes, as the nature of the pressure involved differs fundamentally, one being purposive and the other non-purposive.

However, when we examine the role of "selective pressure" within the relevance generalization, we find that intentionality does not affect the causal relationship at stake. Whether the selection is purposeful or not does not alter the outcome, namely the accumulation of adaptive traits, because unconscious selection can likewise result in such accumulation and, ultimately, phenotypic change. For instance, Siberian Huskies have retained thick fur due to deliberate human selection, while polar bears possess insulating fur as a result of adapting to harsh arctic conditions, without any guiding intent. Nature may lack purpose, but sustained environmental pressures can still lead to the accumulation of adaptive traits and thereby to morphological transformation.

Therefore, within the structure of this analogical argument, the difference in intentionality between artificial breeding and natural species generation does not undermine the cogency of either the similarity generalization or the relevance generalization. In this respect, Wallace's criticism fails to significantly weaken the argument.

Second, regarding the relevance generalization G_2, we have already established that trait modification is a feature of particular interest within the argumentative context concerned with species

transformation, and that such modification can occur over a short time span in artificial breeding. Moreover, it is well-documented that humans can bring about significant changes in biological traits through selective breeding in just a few generations. Based on this, the following relevance generalization can be formulated: whether in artificial breeding or in natural species generation, selective pressure leads to trait modification.

To assess the cogency of the relevance generalization, we proposed several critical questions (CQ2'–CQ6') to assess its cogency:

- CQ2': Are there any context-relevant conflicting features that weaken the similarity and relevance generalizations within the argumentative context of species transformation?
- CQ3': Within the context of species transformation, can the proposition corresponding to trait modification be meaningfully evaluated as true in artificial breeding?
- CQ4': In the case of artificial breeding, is the association between selective pressure and trait modification sufficiently well-established?
- CQ5': Are there any non-conflicting but divergent features that are sufficiently important in this context to weaken the plausibility of the relevance generalization?
- CQ6': Does trait modification conflict with any known features of natural species generation?

We have already addressed CQ2' in detail. CQ3' and CQ4' are relatively straightforward, as they involve reaffirming widely accepted empirical claims. However, CQ5' and CQ6' provide more substantive grounds for critically assessing the strength of the analogical argument.

Notably, Wallace's objection regarding the difference in timescale corresponds directly to CQ5'. Wallace argued that humans, through intensive selective breeding, can induce drastic trait modifications

within a short period, whereas natural selective pressures tend to be weaker and more diffuse. As a result, adaptive traits accumulate slowly in nature, and significant trait modification occurs only over extended timescales. On this basis, he questioned whether the relevance generalization, namely that selective pressure leads to trait modification, holds in the natural case, suggesting that natural selection might be insufficient to drive substantial phenotypic changes.

However, this objection overlooks the continuity of selective pressure intensity. While natural selection may indeed be weaker than artificial selection, its effects can accumulate over far longer periods. Given sufficient time, even modest selective pressures may produce substantial and stable evolutionary outcomes. Thus, although Wallace's critique highlights a divergence between artificial and natural contexts, it offers only limited grounds for undermining the plausibility of the relevance generalization in Darwin's analogical argument.

In fact, Darwin directly responded to this line of criticism. He provided empirical examples in which natural species underwent rapid trait changes under specific environmental conditions, thereby reinforcing the plausibility of the relevance generalization. Notable cases include the industrial melanism of the peppered moth in the late 19th and early 20th centuries and the evolution of insecticide resistance in mosquitoes over just a few decades. Moreover, with the advancement of genetics, researchers later discovered that the rate of gene frequency change, in both natural and artificial selection, follows the same mathematical principles (Haldane 1926). This convergence in underlying mechanisms further strengthens the plausibility of the relevance generalization assumed in Darwin's analogical argument.

Wallace's third objection, which concerns the difference in genetic mechanisms, corresponds to critical question CQ6'. He argued that many of the trait changes observed in artificial breeding depend on inbreeding, and if natural species generation were genuinely analogous to artificial breeding, it too should rely on inbreeding to

produce trait variation. However, this would conflict with the known mechanisms of genetic diversity in natural populations. In Wallace's view, inbreeding should be considered a key factor influencing trait change, and if trait change in natural species also relied on inbreeding (which, at the time, could not be definitively confirmed or denied), the expected result would be a loss of genetic diversity. This outcome would be incompatible with the empirical observation of high genetic variation in natural populations.

This objection was considered significant in the 19th century, as it pointed to a potential conflict between the conclusion of the analogical argument and known features of natural populations. However, with the discovery of Mendelian laws clarifying the relationship between genotypic variation and phenotypic selection, and with the advancement of research in areas such as diversified breeding techniques, genetic bottlenecks in wild populations, and population genetics models, this apparent contradiction was eventually resolved. Of course, as evolutionary biology has progressed, the differences between artificial breeding and natural species generation have also been increasingly acknowledged. Nonetheless, artificial selection experiments continue to serve as simplified models for understanding the processes of natural evolution and remain valuable for scientific explanation and hypothesis testing.

As demonstrated, the critical questions derived from the generalization-based scheme of analogical argument allow for a more precise analysis of how specific objections engage with the structure of the reasoning, in contrast to traditional sets of critical questions. While all three of Wallace's objections focus on differences between artificial breeding and natural species generation, not all of these differences challenge the similarity component of the analogy, nor do they undermine the argument with equal force. By contrast, the generalization-based framework enables a clear distinction between objections that target the similarity generalization (e.g., teleology) and those that primarily challenge the relevance generalization (e.g., temporal scale or hereditary mechanisms). Each objection

corresponds to a specific critical question, such as CQ2', CQ5', or CQ6', thereby supporting a more nuanced and systematic evaluation of the analogical reasoning.

This demonstrates that the generalization-based scheme of analogical argument offers a systematic and practicable framework for analyzing and evaluating analogical reasoning. By reconstructing the similarity and relevance generalizations embedded in an analogy, we gain a clearer understanding of the relationships between analogical cases and the interplay among their respective features. Such understanding, whether of underlying structural parallels or of the connections between relevant properties, is itself a core outcome of analogical reasoning. Hypotheses like the claim that selective pressure leads to trait modification are not merely assumed to support a conclusion; they are often among the very insights that analogical arguments are intended to generate. Furthermore, the critical questions directed at similarity and relevance generalizations clarify the scope and force of potential objections, enabling more precise and rigorous responses to challenges against the analogy.

9. Conclusion

By examining how scholars from different research paradigms conceptualize generalization in analogical reasoning, this paper highlights the multiple and pivotal roles that analogical generalizations play. They not only represent the similarity between analogues, but also mediate the construction of relevance between premises and conclusions. In some cases, generalizations may even emerge as derived conclusions, offering deeper insight into the structural parallels embedded within the analogy.

Uncovering and articulating these generalizations in concrete analogical practice can illuminate the shared features, rules, and patterns underlying the analogues; clarify the inferential basis and key evaluative criteria supporting the analogical conclusion; and facilitate the identification of further potential analogues that may

strengthen the argument. Building on these insights, we propose an extended scheme of analogical argument, one that explicitly models how generalizations structure both similarity and relevance while also incorporating the contextual constraints that shape analogical generalization.

Furthermore, we argue that although analogical generalization may bear a formal resemblance to the type of generalization found in inductive or deductive reasoning, it remains fundamentally empirical, hypothetical, and context-sensitive. These characteristics not only underscore the distinctiveness and autonomy of analogical reasoning, but also reflect its inherent defeasibility and epistemic uncertainty. Accordingly, analogical generalization functions both as a productive argumentative resource and as a potential point of vulnerability, making its systematic analysis and evaluation all the more essential.

To this end, the paper adopts and extends the method of critical questions from informal logic by introducing a new set of questions focused on analogical generalization. Through a case analysis of Darwin's argument for evolution, we demonstrate the practical value of these questions in identifying argumentative weaknesses, clarifying points of contention, and formulating effective responses to criticism. This analysis underscores not only the theoretical significance of analogical generalization in modeling argument structure, but also its practical utility in the interpretation and evaluation of concrete analogical arguments.

In sum, this paper's systematic analysis of analogical generalization contributes to a deeper understanding of the internal structure of analogical argument and lays a foundation for the development of more nuanced, dynamic, and operational frameworks for its evaluation. Generalization is not merely a component of analogical reasoning; it can be regarded as the central engine that drives both its cognitive utility and logical force.

Looking ahead, analogical generalization, as a bridge between similarity and relevance and between the particular and the general,

opens up promising directions for further research. While this paper has outlined preliminary conditions for its cogency, the task of constructing more effective and context-sensitive generalization structures, particularly in cross-domain reasoning and AI modeling, remains an open and pressing challenge. We contend that a deeper investigation into the mechanisms of analogical generalization will not only strengthen the theoretical foundations of analogical argument, but also contribute to the development of operational reasoning strategies in domains such as scientific discovery, explainable AI, and legal reasoning.

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References

Ashley, Kevin D. 1991. Reasoning with cases and hypotheticals in HYPO. *International Journal of Man-Machine Studies*. 34(6):753–796.

Barker, Evelyn M. 1989. Beardsley's theory of analogy. *Informal Logic*. 11(3):185–94.

Bartha, Paul F. A. 2010. *By parallel reasoning: the construction and evaluation of analogical arguments*. New York: Oxford University Press.

Beardsley, Monroe C. 1975. *Thinking straight*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Botting, David. 2012. The paradox of analogy. *Informal Logic*. 32(1):98–115.

———. 2017. The cumulative force of analogies. *Logic and Logical Philosophy*. 27(1):105–41.

Darwin, Charles. 1964. *On the origin of species: a facsimile of the first edition*. Cambridge, MA: Harvard University Press.

Davies, Todd R. 1988. Determination, uniformity, and relevance: Normative criteria for generalization and reasoning by analogy. In *Analogical Reasoning: Perspectives of Artificial Intelligence, Cognitive Science, and Philosophy*, ed. David H. Helman, 227-250. Dordrecht: Springer Netherlands.

Falkenhainer, Brian, Kenneth D. Forbus and Dedre Gentner. 1989. The structure-mapping engine: algorithm and examples. *Artificial Intelligence*. 41(1):1–63.

Freeman, James B. 2013. Govier's distinguishing *a priori* from inductive arguments by analogy: implications for a general theory of ground adequacy. *Informal Logic*. 33(2):175–94.

Gentner, Dedre. 1983. Structure-mapping: a theoretical framework for analogy. *Cognitive Science*. 7(2):155–70.

Gentner, Dedre and Christian Hoyos. 2017. Analogy and abstraction. *Topics in Cognitive Science*. 9(3):672–93.

Godden, David and John Grey. 2021. Reasoning by grounded analogy. *Synthese*. 199(3):5419–53.

Govier, Trudy. 2010. *A practical study of argument*. 7th ed. Belmont, CA: Cengage Learning.

Guarini, Marcello. 2004. A defence of non-deductive reconstructions of analogical arguments. *Informal Logic*. 24(2):153–68.

———. 2023. A case study of contextual and emotional modulation of source-case selection in analogical arguments. *Informal Logic*. 43(3):310–51.

Gust, Helmar, Ulf Krumnack and Kai-Uwe Kühnberger. 2007. Integrating analogical and inductive learning at different levels of generalization. In *LNVD 2007 Learning from Non-Vectorial Data*, eds. Kai-Uwe Kühnberger, Peter König, Petra Ludewig, 46–57. Osnabrück: Institute of Cognitive Science.

Haldane, J. B. S. 1926. A mathematical theory of natural and artificial selection. *Mathematical Proceedings of the Cambridge Philosophical Society*. 23(4):363–72.

Hesse, Mary B. 1966. *Models and analogies in science*. Notre Dame: University of Notre Dame Press.

Juthe, André. 2005. Argument by analogy. *Argumentation*. 19:1–27.

———. 2015. Analogical argument schemes and complex argumentation. *Informal Logic*. 35(3):378–445.

———. 2020. A defense of analogy inference as *sui generis*. *Logic and Logical Philosophy*. 29(2):259–309.

Kotovsky, Laura and Dedre Gentner. 1996. Comparison and categorization in the development of relational similarity. *Child Development*. 67(6):2797–2822.

Lewis, Martha and Melanie Mitchell. 2024. Using counterfactual tasks to evaluate the generality of analogical reasoning in large language models. *arXiv*:2402.08955 [cs.AI].

Liao, Yanlin. 2024. The distinctiveness problem of analogical arguments. *Informal Logic*. 44(1):65–101.

Macagno, Fabrizio. 2017. The logical and pragmatic structure of arguments from analogy. *Logique et Analyse*. 240(0):465–489.

Maxwell, James Clerk. 1890. *The scientific papers of james clerk maxwell*. Cambridge: Cambridge University Press.

Mitchell, Melanie. 2021. Abstraction and analogy-making in artificial intelligence. *Annals of the New York Academy of Sciences*. 1505(1):79–

101.

Mitchell, Melanie, Alessandro B. Palmarini and Arseny Moskvichev. 2023. Comparing humans, GPT-4, and GPT-4V on abstraction and reasoning tasks. *arXiv*:2311.09247 [cs.AI].

Ohkawa, Takenao, Toshiaki Mori, Noboru Babaguchi and Yoshikazu Tezuka. 1992. Analogical generalization. In *Proceedings of the International Conference on Fifth Generation Computer Systems*, 497–504. Amsterdam: IOS Press.

Opiełka, Gustaw, Hannes Rosenbusch and Claire E. Stevenson. 2025. Analogical reasoning inside large language models: concept vectors and the limits of abstraction. *arXiv*:2503.03666 [cs.CL].

Oxford English Dictionary. 2024. Generalization (n.), sense 1.a. *Oxford English Dictionary*. URL accessed 15 August 2025: https://doi.org/10.1093/OED/8342955435.

Schauer, Frederick. 2014. Analogy in the supreme court: lozman v city of riviera beach, florida. *The Supreme Court Review*. 2013:405–32.

Schmidt, Martin, Ulf Krumnack, Helmar Gust and Kai-Uwe Kühnberger. 2014. Heuristic-Driven Theory Projection: An overview. In *Computational Approaches to Analogical Reasoning: Current Trends*, eds. Henri Prade and Gilles Richard, 163-194. Berlin, Heidelberg: Springer.

Wallace, Alfred Russel. 1889. *Darwinism: an exposition of the theory of natural selection, with some of its applications*. New York: Humboldt.

Waller, Bruce N. 2001. Classifying and analyzing analogies. *Informal Logic*. 21(3):199–218.

Walton, Douglas. 2012. Story similarity in arguments from analogy. *Informal Logic*. 32(2):190–218.

———. 2014. Argumentation schemes for argument from analogy. In *Systematic Approaches to Argument by Analogy*, ed. Henrique Jales Ribeiro, 23-40. Cham: Springer International Publishing.

Walton, Douglas and Curtis Hyra. 2018. Analogical arguments in persuasive and deliberative contexts. *Informal Logic*. 38(2):213–62.

Walton, Douglas, Christopher Reed and Fabrizio Macagno. 2008. *Argumentation schemes*. Cambridge: Cambridge University Press.

Webb, Taylor, Keith J. Holyoak and Hongjing Lu. 2023. Emergent

analogical reasoning in large language models. *Nature Human Behaviour*. 7(9):1526–41.

Weitzenfeld, Julian S. 1984. Valid reasoning by analogy. *Philosophy of Science*. 51(1):137–49.