Dimensional Transition Logic

Epistemic Transitions and the Scope of Their Formalization

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Abstract

Four-dimensional logic examines how statements emerge from immediate associations, are formulated as determinate relations, are examined with respect to their presuppositions, and are situated within their contexts of validity. It distinguishes D1 as the immediate and associative dimension, D2 as the systematic and rule-governed dimension, D3 as the reflexive dimension, and D4 as the contextual and perspectival dimension. Classical bivalence is retained. The dimensions concern the epistemic function of operations and introduce neither additional truth values nor ontological domains. Drawing on Piaget's genetic epistemology, this framework is developed as a reconstruction of cognitive capacities. Its purpose is to expose unwarranted transfers between abstractions, levels of description, and domains of validity. Quotient formation formalizes a particular transition of abstraction within D3. Its mathematical precision, however, captures neither the full reflexive function of this dimension nor the substantive adequacy of the chosen aspect. A condition for transferring properties to equivalence classes and a typing of relations specify two distinct tasks of reflexive examination. D4 additionally marks the perspectival character of the chosen framework and applies this determination to the theory itself. A running football example illustrates the transitions and their limits.

1 Subject and Scope

A statement may be true within a particular framework and yet be misused in a broader argument. A team's victory, for example, does not entail that it played with tactical superiority. A club's high revenues do not entail social benefit. In each case, the error lies in a transfer whose additional presuppositions remain unspecified. The words used may remain unchanged even though the object, the criterion of assessment, or the asserted relation has changed.

Four-dimensional logic addresses such transitions. It examines what happens when a perceived association becomes a determinate relation, when that relation's presuppositions become objects of inquiry, and when the scope of the resulting statements is established. The classical distinction between true and false remains the logical core. A statement must, however, be sufficiently determinate before its truth can meaningfully be assessed. This determination includes the meanings of its concepts, the kind of relation asserted, and the framework of its application.

The term dimensional logic therefore designates an epistemic extension of the analysis of logical thinking. This extension concerns the formation, examination, and use of statements. It does not replace classical rules of inference with rules specific to each dimension. Reflection and contextual examination can likewise employ ordinary logical and mathematical procedures. What matters is the function these procedures perform in the relevant epistemic setting.

An earlier account introduced the four dimensions and corresponding transition operators (Stegemann 2026a). The subsequent transition logic specified a transition of abstraction through quotient formation and developed D4 as reflexive relativization (Stegemann 2026b). The study of association, relation, and category errors added an explicit examination of levels of description and relation signatures (Stegemann 2026c). The present revision brings these determinations together and clarifies their scope.

Quotient formation is identified as a formal model of a D3 operation. The broader reflexive function of D3 is defined in its own right.

The aim is a justified procedure for epistemic error control. It should show what further specification a statement requires and where a broader claim calls for an independent justification. This does not amount to a claim to provide a complete calculus of all epistemic operations.

2 Cognitive Origins and Epistemic Function

The starting thesis is that logic and epistemology arise from human cognition and that their genesis must be explained in terms of it. Piaget's genetic epistemology provides a point of reference. Piaget investigates the development of logical structures from the coordination of actions. In reflective abstraction, determinations belonging to a preceding organization are taken up and reorganized at another level. At the same time, he distinguishes the psychological explanation of such transitions from their logical assessment. His genetic epistemology connects the study of the genesis of knowledge with the analysis of its forms (Piaget 1970, first lecture).

Dimensional logic takes up this question. It reconstructs capacities that remain simultaneously available in developed thought. D1 to D4 designate neither age groups nor a fixed temporal sequence of individual acts of thinking. A reflexive investigation can prompt a new association. An examination of context can require a new formal derivation. The cognitive development of these possibilities must be distinguished from their subsequent use.

The cognitive origins of logical operations must likewise be distinguished from the justification of a particular inference. An inference is not valid because it is frequently or spontaneously made. Its validity depends on the rules on which it rests. The cognitive question concerns how human beings can form, apply, and make such rules objects of inquiry. The epistemic question additionally concerns the conditions under which their application justifies a statement about the object under investigation.

The division into four dimensions is a functional reconstruction informed by Piaget, not a direct transposition of his developmental stages. It distinguishes immediate association, the establishment of determinate relations, reflexive examination, and reflexive contextualization. This does not claim to provide an empirically exhaustive account of all possible cognitive capacities. The task is to justify why these distinctions perform different functions in the scrutiny of statements.

The division into dimensions does not introduce corresponding domains of being. Different approaches to a football match multiply neither the match nor its mode of existence. They change which relations within the same event are grasped and which questions are asked about it. The bivalent logic used here remains unchanged.

3 The Four Dimensions

D1 Immediate Distinction and Association

D1 designates the immediate apprehension of differences and the association of what belongs together for a system. A movement may be associated with danger, a sound with expectation, or a perceived arrangement with a familiar action. The kind of connection need not yet be explicitly specified. Temporal proximity, similarity, repeated co-occurrence, and learned relevance can all support an association.

In football, a spectator follows movements, reacts to a pass, and associates the approach to the goal with excitement. This association does not presuppose a developed theory of the move. It can prompt later analysis but does not yet contain a justified specification of its presuppositions.

Distinguishing two states does not already amount to assigning the truth values true and false. D1 initially concerns the emergence of possible objects and connections of thought. A truth-apt statement arises only when a determinate content is formulated. The linguistic description of a D1 response must therefore not be confused with the response itself.

D2 Determinate Relations and Rule Governed Inference

D2 begins with the explicit specification of a connection. A mere association becomes, for example, a similarity, a correlation, a causal hypothesis, or a logical consequence relation. Which of these relations is intended forms part of the statement's content. Their occurrence in the same linguistic setting does not make them interchangeable.

A tactical analysis may claim, for example, that a particular pattern of movement opens a passing lane. Movements are no longer merely associated. A determinate relation between positions, actions, and possibilities for action is asserted. Its assessment accordingly requires determinate observations and presuppositions.

Within a fixed formal framework, statements are combined according to classical rules. The validity of an inference and the truth of its premises remain different questions. A valid inference can correctly draw consequences from an unsuitable premise. Examining its form therefore does not yet determine whether the concepts and relations employed are adequate to the object.

D3 Reflexive Abstraction and Examination of Presuppositions

D3 addresses the determinations through which a relation is established and assessed. Cases can be grouped into classes under a chosen aspect. The categories, rules, and presuppositions of such a classification can likewise be examined. What these operations share is that determinations previously employed become objects of inquiry in their own right.

A tactical analysis operates on D3 when it asks what understanding of gaining space or controlling play underlies its assessment. An investigation of football's place within sport can operate on D3 by identifying features shared by different sports and examining the suitability of those features. The dimension is determined by the operation, not by the word sport or the size of the domain considered.

D3 therefore encompasses more than class formation. Examining whether a causal expression has the same meaning in two systems of description is a different task from grouping cases together. Both tasks can be supported by formal methods. Their different procedures perform a common reflexive function.

D4 Reflexive Contextualization

D4 determines how a statement is bound to a context while also taking into account that the selection of this context itself proceeds from a perspective. The criteria under which different descriptions are compared therefore have no standpoint free of presuppositions. This determination includes dimensional logic itself.

Economic, sporting, and societal approaches to football can capture different relations within the same event. D4 does not consist merely in switching between these subjects. It becomes operative when the

scope of the chosen approach and the standpoint from which it is selected are explicitly taken into account. A societal approach is likewise no comprehensive standpoint that definitively encompasses all other perspectives.

The four dimensions do not form mutually isolated domains of thought. An investigation on D3 or D4 can infer and prove on D2. D2 designates the rule-governed execution, while D3 and D4 determine the reflexive or contextual function of that execution. A single line of argument can therefore involve several dimensions.

4 Dimensions of Thought and Levels of Description

Dimensions of thought must be distinguished from levels of description. A dimension of thought designates the kind of epistemic operation. A level of description designates the conceptual and methodological approach through which an object is apprehended. Both contribute to the perspective of an investigation, but they perform different functions.

A football match can be described as a sequence of bodily movements, as tactical cooperation, as a contest governed by rules, or as an economic event. Within each of these approaches, the four dimensions of thought can be operative. An economic investigation can also begin with a spontaneous association, formulate a determinate relation, examine its categories, and reflect on its contextual presuppositions.

Levels of description need not form a continuous hierarchy of increasing abstraction. A tactical and an economic description may address different questions without either fully encompassing the other. At the same time, abstraction can generate a new domain of objects, as when individual matches are grouped into classes with the same type of outcome. Dimensional analysis must therefore indicate in each case whether it concerns an abstraction, a change of descriptive system, or a change in the context of validity.

For formal notation, let E be a set of levels of description and T a set of sufficiently determinate expressions. A level operator assigns an expression its descriptive type:

$$\lambda: T \to E.$$

The assignment concerns the expression in its determinate use. The same word can receive different assignments in different uses. Success, for example, can designate a match result, a tactical assessment, or a financial outcome. These meanings must be distinguished before a formal examination is undertaken. The typing describes neither additional objects nor separate ontological strata.

5 Quotient Formation as a Model of Abstraction

The Chosen Aspect

A particular transition of abstraction can be represented by quotient formation. Let F be a nonempty set of cases. An aspect a specifies an equivalence relation $\sim_a$ on F. The relation is reflexive, symmetric, and transitive. Two cases count as equivalent precisely with respect to this aspect.

The equivalence class of a case x and the quotient are defined by

$$[x]_a = \{y \in F : y \sim_a x\}, \qquad F/\sim_a = \{[x]_a : x \in F\}.$$

The corresponding map assigns each case its class:

$$q_a: F \to F/{\sim_a}, \qquad q_a(x) = [x]_a.$$

Consider, for example, four matches played by a team. Two were won, one ended in a draw, and one was lost. If only the outcome category is selected, three classes result. Differences in style of play, opponent, and economic conditions are not captured by this classification. Under the aspect of tactical organization, the same set of matches can be partitioned differently.

Class formation thus specifies which differences are disregarded in the current investigation. It does not determine whether these differences are likewise irrelevant to a different question. Its epistemic significance lies precisely in this selection.

Scope of the Formalization

Quotient formation is an ordinary mathematical construction. It requires neither modified rules of inference nor a new truth value. Its assignment to D3 concerns the use of this construction to examine a classification explicitly. Once the set of cases and the relation have been fixed, the construction can be carried out according to fixed rules. This does not yet clarify the origins or adequacy of those specifications.

Quotient formation therefore formalizes a particular case of reflexive abstraction. It is not a complete definition of D3. Examining presuppositions, investigating axioms, and checking relation signatures are not already accomplished by forming classes. Each of these tasks requires appropriate procedures and justifications.

A change in the domain of objects likewise does not by itself generate a new logic. Moving from matches to classes of matches makes it possible to examine properties of these classes. Such properties are not automatically properties of the individual matches. Both domains of objects can nevertheless be described by classical logical and mathematical means. An epistemic change of level must be distinguished from the choice of formal calculus.

A Limited Measure of Coherence

Not every similarity relation is transitive. One case can resemble a second and the second a third, while the first and third no longer count as similar under the chosen criterion. For a reflexive and symmetric relation, one can examine how often the transitivity condition is satisfied.

For the following definition, let F be finite and nonempty. The triples are ordered, and repeated elements are counted. Define

$$A_a = \{(x, y, z) \in F^3 : x \sim_a y \ \wedge \ y \sim_a z\}$$

and

$$B_a = \{(x, y, z) \in A_a : x \sim_a z\}.$$

The degree of coherence is

$$C_F(a) = \frac{|B_a|}{|A_a|}.$$

By reflexivity, A_a contains at least the triples (x, x, x), so the denominator is positive. Since B_a is a subset of A_a, the value lies between zero and one. The value one is reached exactly when every instance

satisfying the antecedent also satisfies the consequent. This is precisely transitivity. Under the stated assumptions, the relation is then an equivalence relation.

For three cases u, v, and w, where the only relations besides the reflexive ones are $u \sim_a v$ and $v \sim_a w$ together with their symmetric counterparts, there are seventeen triples in A_a. Two violate the consequent. The value is therefore $15/17$. The relation does not generate a disjoint partition into equivalence classes.

This value measures only a formal property of the chosen relation on the chosen set of cases. It is neither a degree of truth nor a measure of adequacy to the object. A substantively irrelevant classification can be perfectly transitive. Moreover, the selection of cases and the counting convention affect the numerical value. Comparisons between different investigations therefore require additional specifications. Infinite sets would require a suitable measure structure; the present counting formula cannot simply be extended to them.

6 Conditions for a Warranted Transfer

Properties Within an Equivalence Class

The formation of an equivalence class justifies treating its elements alike only with respect to the chosen relation. If a further property is to be transferred to the classes, it must be examined whether that property is preserved within every class.

Let $P: F \to \{0,1\}$ be the characteristic function of a determinate property of the cases. This property can be expressed uniquely as a property of the classes if and only if it is constant on every equivalence class:

$$\forall x, y \in F: \quad x \sim_a y \;\Rightarrow\; P(x) = P(y).$$

In this case, there is a uniquely determined map $\overline{P}: F/\sim_a \to \{0,1\}$ such that

$$P = \overline{P} \circ q_a.$$

The justification is straightforward. If x and y are representatives of the same class, the value assigned to that class must be independent of which representative is chosen. This requires $P(x) = P(y)$. Conversely, given this constancy, the class value can be defined by $\overline{P}([x]_a) = P(x)$ without the choice of representative affecting the result.

Two matches that were won are equivalent with respect to their outcome type. This does not entail equality of tactical quality. If these matches are grouped under the feature won, the property tactically superior is not already determined by class formation. It would have to be established independently. Only if it is genuinely invariant under the chosen equivalence can it be attributed to the class in this sense. This invariance is an additional statement about the cases.

Statistical statements remain possible when a property varies within a class. In that case, however, what is determined may be a proportion rather than a property of all members. A proportion does not entail a universal attribution. The kind of statement must be preserved or explicitly changed in the transition from cases to classes.

Relation Signatures and Levels of Description

Transfer between levels of description poses a different task. Here, class formation is insufficient as a formal model. A binary relation R is therefore assigned a signature specifying the descriptive types between which it is defined:

$$\mathrm{Sig}(R) \subseteq E \times E.$$

For sufficiently determinate expressions x and y, the condition of type compatibility is

$$\mathrm{WF}_{\lambda,\mathrm{Sig}}\big(R(x,y)\big) \quad \Leftrightarrow \quad \big(\lambda(x),\lambda(y)\big) \in \mathrm{Sig}(R).$$

Here, WF designates only well-definedness with respect to this typing. It determines neither the truth of the statement nor its full explanatory force. The signature may explicitly include connections between different levels of description. An empirical correlation between a physiological measurement and a reported sensation can be defined as such a connection.

A type violation initially shows that the asserted relation is inadmissible under the specified definitions. The philosophical diagnosis of a category error additionally requires an examination of these definitions. A legitimate extension of meaning may not yet have been specified. A particular bridging relation may be justifiable. Only when such a justification is absent is the original relation being transferred without sufficient grounds. The assignment of types therefore cannot itself be treated as an unquestionable presupposition.

Restricting admissible applications by means of types has an established history in logic, for example in Church's simple theory of types (1940). The descriptive types used here, however, are specified for an epistemic analysis. Labels such as physiological or economic are not categories derived directly from a formal type theory. Their selection and demarcation require substantive justification.

The Common Object of Reflexive Examination

Quotient formation and type checking are different procedures. The former makes explicit which differences are disregarded under a chosen aspect. The latter makes explicit the kinds of expressions to which a relation may be applied. What they share is an examination of determinations that ordinary application already presupposes.

D3 can therefore examine whether an asserted transfer preserves a property within a class or changes the meaning of a relation between levels of description. Neither examination is replaced by the other. Both prevent a locally justified treatment as equivalent, or a locally justified relation, from being extended without further justification.

The functional equivalence of two systems, for example, permits their assignment to the same functional class. If this is to entail that they share further properties, the invariance of those properties within the class must be justified. If the argument also moves from a functional to a phenomenal description, the connecting relation must be explicitly specified. An additional identity assumption can complete the argument formally. Its substantive justification, however, does not follow merely from its inclusion as a premise. Dimensional analysis thus locates the task of justification; it does not accomplish it by assigning a type label.

7 D4 and Validity Under Perspectives

Context and Truth

A statement with compatible types may still claim too broad a scope of validity. A relation that holds under particular playing conditions need not hold for other opponents, rules, or forms of competition. Specifying the context therefore forms part of examining its scope.

A context may specify, for example, the rules assumed, the population investigated, a period of time, or the conditions of a measurement. A formal indexing of truth by contexts was already explicitly developed by McCarthy (1993). For dimensional analysis, it is additionally crucial that the selection and demarcation of the context itself remain epistemic achievements requiring justification.

For a statement sufficiently determinate within the relevant framework, its evaluation can be indexed by an aspect a and a context c:

$$v_{a,c}(\varphi) \in \{0,1\}.$$

This notation adds no third truth value. It makes the presuppositions of interpretation explicit. An expression that is not yet determinate does not thereby bear an additional truth value. Likewise, a lack of knowledge about which value applies must be distinguished from the number of truth values.

Different evaluations may arise from different meanings or conditions of application. They may also express a genuine substantive contradiction. If two people evaluate the same sufficiently determinate statement in opposite ways under the same conditions, their conflict is not resolved merely by invoking perspective. Contextual analysis must show whether they are actually making different statements or disagreeing in their assessment of a common object. The social acceptance of a statement must likewise be distinguished from its truth.

Reflexive Relativization

D4 goes beyond specifying a boundary condition. The dimension designates the recognition that the standpoint from which contexts are selected and compared is itself a particular standpoint. D3 can compare different frameworks under a criterion held fixed for the investigation. D4 takes into account the perspectival character of this criterion and of the investigation itself.

A further abstraction would again specify an aspect. It could thereby enable an additional comparison but would remain an abstraction under that aspect. Repeated class formation therefore does not by itself establish a fifth or sixth epistemic dimension. D4 performs a different function: it denies a standpoint the claim that its use alone gives it a definitive position in relation to all others.

The reflexive index $\rho(\varphi)$ can be used as shorthand for this marking. Here, it is neither a new truth-functional operator nor an additional rule of derivation. The notation marks an epistemic obligation to take into account the conditions and scope of one's own judgment. Statements about D1 to D4 are subject to this obligation as well.

In this sense, D4 is virtual. It does not open up a position outside all perspectives that could actually be occupied. Its function is to refrain from presupposing such a position, including for one's own investigation. Renewed reflection on D4 continues the same self-application. It produces no closure free of presuppositions.

Justified Selection Without Absolute Priority

The perspectival character of descriptions does not entail that they are all equally valid. For a particular question, one aspect may be better justified than another. To determine which team won, one needs the competition rules and the established result. Investigating the economic consequences requires different quantities. D4 permits justified selection and requires its purpose and presuppositions to be made explicit.

The objects themselves also constrain selection. Data may contradict a hypothesis, an operationalization may fail to capture its object, and a transfer may fail because properties are not preserved. The fact that these tests themselves take place under particular conditions does not remove their force within those conditions.

A family of admissible aspects H can be specified for an investigation. Insofar as these are represented by reflexive and symmetric relations on the same finite set of cases F, the coherence profile

$$K_F(H) = \{(a, C_F(a)) : a \in H\}$$

can be given. This profile juxtaposes different formal coherence values. It is neither a truth profile of a particular statement nor a complete representation of D4. Among other things, it lacks a substantive assessment of the aspects and an examination of their selection. An aggregation of the values may be useful for a particular task but requires an explicitly justified weighting. It does not thereby yield an overall value independent of perspective.

8 The Football Match as a Running Test Case

Suppose a team wins a match. This is a hypothetical test case and makes no claim about a particular team. A spectator immediately associates quick attacks and the cheering after a goal with success. On D1, this association is a response to the perceived event. It may prompt a later investigation but does not yet determine which kind of success is to be explained.

On D2, a determinate statement is first formulated. Under the specified competition rules, the team has won. Under an appropriate definition, it can correctly follow that the team was successful with respect to the match result. A second statement might claim that a particular tactical arrangement made the victory possible. This statement requires further presuppositions. The established result does not justify it on its own.

On D3, the classification employed is examined first. If matches are classified solely as won, drawn, or lost, their tactical quality is not part of the equivalence relation. The transition from the result to tactical superiority therefore requires an additional justification. Quotient formation shows what is preserved in the class. Reflexive investigation examines whether the newly introduced feature is genuinely invariant within this class or must be assessed independently.

The statement is now extended: the victory was economically successful and therefore demonstrates the club's societal significance. Further systems of description enter the argument. Sporting success, an economic surplus, and social benefit are determined by different criteria. They can be connected, but the continued use of the word success does not establish that connection. An investigation would have to explain, for example, how the match result affects revenues and under what normative or empirical criterion a societal assessment is derived from this.

Signature checking can make these transitions explicit. It replaces neither an investigation of the economic relationships nor a justification of the societal criterion. An explicitly formulated connecting premise makes an argument intelligible; only its independent justification supports the further inference. Examination must therefore not stop at verbally marking the transition.

On D4, the conditions of validity and the standpoint of the entire analysis are taken into account. The connection between victory and revenues may depend on the competition and the period considered. An assessment of social benefit may assign different weights to different interests and consequences. Comparing these assessments in turn requires an aspect under which the comparison is made. This aspect can be justified without thereby occupying a standpoint outside all possible assessments.

The result of the analysis is not a general relativism about the match result. Under the assumed rules, it remains determinate who won. What is examined is which further statements this result supports. Four-dimensional analysis thus distinguishes immediate association, the determinate assertion, its presuppositions requiring reflexive examination, and the scope of its claim to validity. Its contribution lies in reconstructing the argument, not in providing an additional scale of assessment beyond true and false.

9 Limits and Outstanding Tasks of Justification

Dimensional logic provides no general decision procedure for true or adequate statements. It organizes different tasks of examination. Which observation supports a causal relation, which operationalization is suitable, or which normative premise is convincing must be justified within the relevant investigation. Assigning a dimension can locate this work but cannot replace it.

The limits of formalization can be specified in each case. For a fixed equivalence relation, quotient formation is uniquely determined. For a property on the set of cases, constancy on classes is the exact condition for its unique transfer. For fixed types and signatures, a syntactic compatibility check is possible. The substantive suitability of the relation, the correctness of the property attribution, and the justification of the typing do not follow from these formal results alone.

The choice of a set of admissible aspects is likewise task-dependent. No closed totality of all possible perspectives is constructed. Nor does the degree of coherence provide a general measure of epistemic adequacy. Such an identification would itself involve precisely the transfer that the approach seeks to scrutinize.

The reference to cognition does not establish an exclusively psychological criterion of truth. The genesis of a belief and the reasons supporting its content remain distinguishable. Those who wish to test the four dimensions as an empirical model of cognitive development need corresponding investigations. The present paper specifies their epistemic functions and selected formal procedures. This specification does not entail experimental confirmation of a universal sequence of four stages.

The claim to a distinctive contribution therefore does not lie in the invention of quotient formation, typing, or context indexing. It lies in their assignment to a cognitively grounded architecture of statement formation and error control. This assignment must itself be assessed in terms of its conceptual precision and its reconstruction of concrete arguments.

10 Conclusion

Four-dimensional logic examines epistemic operations that are not jointly captured by a purely formal assessment of already specified statements. D1 designates immediate associations. D2 specifies relations and processes them according to rules. D3 examines the abstractions, categories, and presuppositions employed. D4 takes into account their contextual dependence and the perspectival character of one's own standpoint. Classical bivalence remains the logical core of this architecture.

Quotient formation has a specific, limited place within it. It models the grouping of cases under a chosen equivalence relation. The condition of constancy on classes shows when a further property can be transferred to the classes. Checking relation signatures, by contrast, concerns the admissibility of a relation between specified descriptive types. Both procedures support D3 without reducing its entire reflexive function to a single operation.

D4 does not complete this analysis through a further abstraction. It establishes that the criteria employed and dimensional theory itself are formulated under presuppositions. This entails neither an additional truth value nor the arbitrariness of substantive assessments. It entails an obligation to specify the chosen frame of reference and the scope claimed.

A statement must therefore claim no more than its concepts, presuppositions, and examined domain of validity can support. Wherever a broader connection is asserted, the additional link must be justified. This is the epistemic function of dimensional transition logic.

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