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# Thinking with Klein about Integration

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***Abstract:*** Integration is crucial to interdisciplinary and transdisciplinary work and it therefore deserves perennial attention by scholars and practitioners of such work. Few have thought so carefully, deeply, and tenaciously about integration as Julie Thompson Klein. In this article, we recount the development of Klein's thinking on integration, from her early stepwise model in 1990 to her current socio-linguistic model. After summarizing Klein's views, we compare the socio-linguistic model to a more recent view of integration known as the IPO (input-process-output) model. We show how these two models of integration relate to one another, and then we demonstrate their complementarity using an example of integrative argumentation from a Toolbox workshop. We conclude that we can understand instances of cross-disciplinary integration better with both models than with only one or the other. This theoretical stereoscope opens new avenues of research about the types of integrative relations collaborators use, what is involved in social/rhetorical integration, and the extent to which it is feasible to specify all of the parameters in an instance of integration.

***Keywords*:** argumentation, integration theory, interdisciplinarity, Julie Thompson Klein, reasoning

*All interdisciplinary work will be improved by more self-conscious focus on the process of integration.* (Klein, 2001, p. 54)

There are few topics more near and dear to Julie Thompson Klein and to us than integration. The topic is both a personal and professional preoc-

cupation, shared, we know, by nearly all readers of this journal. Many of us have been thinking with Klein about integration for decades. In this article, we provide a scenic overview of our journey, looking intently at where Klein has been and where we might go henceforth together. We begin by reviewing two models of integration that can be recovered from Klein's work – a stepwise model from Klein (in 1990) and what we call the "socio-linguistic model" from her later work. After presenting a model that we favor, the IPO or input-process-output model, we compare it with Klein's socio-linguistic model. We conclude by discussing an example of integrative argumentation from a Toolbox workshop that demonstrates we can understand instances of cross-disciplinary integration better with both models than with only one or the other.

## The Development of Klein's Thinking about Cross-Disciplinary Integration

We begin with two snapshots of Klein's thinking about the concept of *integration*. The first is an early account of integration developed in Klein's 1990 book, *Interdisciplinarity: History, Theory, and Practice.* This early work conducts a wide-ranging survey of the literature then extant on interdisciplinarity. The stepwise model presented in this book represents integration as a roughly linear, algorithmic process, a way of thinking about integration that has had a significant influence on other theorists interested in interdisciplinary process (e.g., Newell, 2001; Repko, 2008). We then describe her more recent view, the "socio-linguistic model," which emerged in subsequent work (e.g., Klein, 2001, 2004a, 2004b; Bruun, Hukkinen, Huutoniemi, & Klein, 2005) and is most clearly and forcefully articulated in her chapter "Research Integration: A Comparative Knowledge Base" in *Case Studies in Interdisciplinary Research* (Klein, 2012).

## The Stepwise Model

We begin our discussion of Klein's view on integration with its early development in *Interdisciplinarity: History, Theory, and Practice* (Klein, 1990). In this seminal book, she provides one of the first systematic accounts of integration in interdisciplinary contexts and the first comprehensive examination of interdisciplinarity and its literature up to that time. Her synoptic take on interdisciplinarity addresses a number of themes that were taken up by others in later work, for example, fragmentation (cf. Bammer, 2013), metaphor (cf. Boix Mansilla, 2010), communication (cf. Thompson, 2009), collabora-

tion (cf. Stokols, Hall, Taylor, & Moser, 2008), and complexity (cf. Newell, 2001; Repko, 2008), to name just a few. Her mastery of the literature and attention to detail support a robust exposition of interdisciplinarity that is historically grounded and international in scope. As she traces themes through the literature, her own view of interdisciplinarity emerges as a function of what she foregrounds and what she backgrounds. Integration figures centrally in her discussions of interdisciplinary activity, and in this section of our article, we reconstruct an account of her thinking in 1990 that will serve as a baseline for understanding her more recent reflections on the topic.

In addition to the fact that the verb "to integrate" and its cognates are used frequently in the book, the preeminence of the noun *integration* in Klein (1990) is underscored by her indication early on that "in general practice" she uses the adjectives "interdisciplinary" and "integrative" "interchangeably" (p. 15). There are moments where she distinguishes the two terms, for example, when allowing that "integration" can be used more broadly to describe features of *multidisciplinary* work, but most of what she writes in the book reflects her views on *interdisciplinary* integration. This emphasis on interdisciplinary integration is reflected in her summary of the book's central argument: "Interdisciplinarity is a means of solving problems and answering questions that cannot be satisfactorily addressed using single methods or approaches" (Klein 1990, p. 196). Whether focused on teaching, research, or practice, interdisciplinary activity is integrative activity, that is, activity that combines methods and approaches in pursuit of a complex understanding that does justice to the complexity of the phenomena under study.

In the book, when Klein asks "What may be said about a concept that is so vast, so complex, and so various?" (Klein 1990, p. 182), she is speaking of *interdisciplinarity*, but given her "general practice," we believe that her question works equally well for *integration*. The complexity of interdisciplinary integration prompts her to examine it from a variety of different perspectives, for example, historic, conceptual, theoretical, contextual, and practical. In the process, she discusses interdisciplinarians' *ways of speaking* about integration, *ways of thinking* about it, and *ways of acting* in light of it.

*Ways of speaking* about integration and interdisciplinarity are an important point of emphasis in Klein (1990), and the book includes one chapter on the interdisciplinary lexicon and another on the rhetoric of interdisciplinarity. Her interest in how we speak about these topics is also reflected in numerous other parts of the book, such as discussions of Burke's (1966, pp. 45-46, 49) description of technical vocabulary as a "terministic screen" and dialogue as an integrating mechanism. Klein's consideration of the subject opens with a historical account of the "evolution" of interdisciplinarity (p.

19) as a look back on what people said about integration in the past. The "area" approach to interdisciplinarity that emerged in American universities in the late 1930s, exemplified by women's studies and American studies, supported a conception of *integration* as *unification* that belonged to a "higher and more powerful category than 'interdisciplinarity'" (p. 26). Similarly, earlier theoretical work in education associated *interdisciplinarity* with "linking existing disciplinary categories" and *integration* with the "transmutation" or "unification" of those categories (p. 27). These early distinctions gave way to the conceptual synthesis that supported the "interchangeable" use of these terms.

A second way of speaking about integration that receives attention in Klein (1990) involves the importance of metaphor to our understanding of the concept. "Bridge-building" and "restructuring" (pp. 27-28) join "fusion" (p. 43), "transmutation" (p. 79), "symbiosis" (p. 80), "borrowing" (p. 85), and many other terms invoking images of different ways things can be brought together. Metaphor is a useful mechanism for making connections across disparate domains; as Lakoff and Johnson (1980) put it, "The essence of metaphor is understanding and experiencing one kind of thing in terms of another" (p. 5). Metaphors are thus "evocative approximations of interdisciplinary cognition" (Boix Mansilla, 2010, p. 289), calling our attention to features of integration that should figure in a more abstract analysis of the concept.

The different *ways of thinking* about integration Klein found in the literature she reviewed for the book help us get beneath the surface of semantics, exposing the structures that justify the similarities expressed by the metaphors. For example, Klein (1990) emphasizes the conceptual connection between *integration* and *differentiation* – to integrate *A* and *B* presupposes that *A* and *B* are differentiated (p. 43), and conversely, "[e]very differentiation postulates the existence of integrated elements" (p. 53). This reinforces the idea that integration involves *putting things together*, which of course entails a starting point where the things in question are not joined or combined. She also recognizes integration as a core process within interdisciplinary activity, calling interdisciplinarity "a process for achieving an integrative synthesis…that usually begins with a problem, question, topic, or issue" (p. 188).

By 1990, analysis of interdisciplinary integration had yielded a variety of distinctions among kinds of integration, and Klein canvasses many of those in the book. For instance, she lists a variety of integrative modalities under four fundamental kinds of interdisciplinary interaction: "(1) borrowing, (2) solving problems, (3) increased consistency of subjects or methods, and (4)

the emergence of an interdiscipline" (Klein, 1990, p. 64). These modalities include *concept interdisciplinarity*, under (1), which involves use of a concept from one discipline to supplement a concept in another (p. 64); *border interdisciplinarity*, under (3), which signifies the creation of an intersection between two closely related disciplines (p. 65); and *structural interdisciplinarity*, under (4), which refers to the formation of the "basic structure" of a new discipline (p. 65). Each of these modalities corresponds to a way of inducing dependencies among different disciplinary inputs to support thinking of them together as one.

A full account of interdisciplinary integration must address how one enacts interdisciplinarity in the world. That is, it must account for the interdisciplinary ways in which educators, researchers, and practitioners operate when pursuing integrative objectives. In discussing integrative techniques, strategies, and frameworks, Klein (1990) provides a rich and nuanced accounting of the practical and conceptual technology that had by then been developed to facilitate integrative activity. Late in the book, she lists 25 integrative techniques for achieving integration, focusing on *iteration* and *role clarification* as two "especially useful" techniques for integrating across disciplines (pp. 189-190). Iteration supports reflective engagement with an ongoing project, where collaborators have the opportunity to take turns being teachers and students, performers and critics. Given such turn-taking, role clarification is crucial as a way of assessing what the collaborators need and expect from one another.

Klein also discusses a number of integrative strategies, which are broader plans of action that constrain decision making about specific steps. These include "devising a set of abstract hypotheses" that can support integration by serving as shared objects of evaluation from different disciplinary points of view (p. 117; cf. the Toolbox approach in O'Rourke & Crowley, 2013), constructing a project "metalanguage" that can be used to coordinate different disciplinary contributions (p. 117), and building a team that includes "system generalists and disciplinary specialists" to iteratively appraise and interpret project data (pp. 190-191).

Another key feature of Klein (1990) is its detailed consideration of several integrative frameworks that provide conceptual structure for thinking and talking about integration, as well as practicing it in particular instances. Some of these are informal (e.g., Sjölander's 1985 description of 10 developmental stages of an interdisciplinary project, pp. 71-73), others are idealized (e.g., deWachter's 1982 model based on the "temporary suspension of all known methods," pp. 192-195), and still others are limited in scope (e.g., the models of integrative organization and communication from Rossini and

colleagues, pp. 129-130; the "four major models of integrative education in the health sciences," p. 151).

The more formal, concrete, and generally applicable models of integrative process that Klein discusses include one from Hursh, Hass, and Moore (1983) and one of her own design. Her process specification for integration includes these 12 steps:

1a. *defining* the problem (question, topic, issue);
b. *determining* all knowledge needs, including appropriate disciplinary representatives and consultants, as well as relevant models, traditions, and literatures;
c. *developing* an integrative framework and appropriate questions to be investigated;
2a. *specifying* particular studies to be undertaken;
b. *engaging* in "role negotiation" (in teamwork);
c. *gathering* all current knowledge and *searching* for new information;
d. *resolving* disciplinary conflicts by working toward a common vocabulary (and focusing on reciprocal learning in teamwork);
e. *building and maintaining* communication through integrative techniques;
3a. *collating* all contributions and *evaluating* their adequacy, relevancy, and adaptability;
b. *integrating* the individual pieces to determine a pattern of mutual relatedness and relevancy;
c. *confirming or disconfirming* the proposed solution [to the problem defined at the start]; and
d. *deciding* about future management or disposition of the task/project/patient/curriculum. (Klein, 1990, pp. 188-189)

This is a stepwise framework for pursuing integrative responses to problems or questions that require them, where integration is understood primarily as a process. As such, the framework outlines a progression from the earliest stages in which the problem or question is defined to the late stages in which the response is confirmed or disconfirmed. In introducing this framework, Klein (1990) acknowledges that there is "no absolute linear progression" to integration (p. 188), which is consistent with her contention that iteration is an important integrative technique. Nevertheless, she defends a model of integration as a process that can be pursued in an algorithmic and orderly fashion.

It is worth lingering for a moment over these steps. Klein organizes them in an order that breaks down into three stages: an *orientation* stage that focuses on understanding the problem or question, a *preliminary* stage that

involves preparing both knowledge and social resources for the business of integration, and an *execution* stage during which the integration itself is effected. Not all of the steps are obviously integrative. Some are – 1c, 2b, 2d, 2e, and of course 3b – but the rest focus on meeting the material or structural preconditions that must be in place before integration can be pursued.

Of the integrative steps, the first four (i.e., 1c, 2b, 2d, and 2e) focus on creating the epistemic, social, and communicative infrastructure conducive to integrative success. Step 3b is really where the action is – that is where the integrative response is generated. Although the specification of 3b largely presents integration as a black box, it does give us an important clue about one condition necessary for the success of integration, namely, that there is "mutual relatedness and relevancy" among the inputs to the integrative process. That is, the process of integration makes process inputs depend on one another, with the integrated result being an assembly of mutually related and mutually relevant parts.

**The Socio-Linguistic Model**

As Klein developed her views, she recognized that her original attempt to describe integration in 1990 was too linear to model the cases of integration she had observed in the earlier history of interdisciplinary work and was observing in her own day. Her 1996 book, *Crossing Boundaries: Knowledge, Disciplinarities, and Interdisciplinarities*, blended her previous, stepwise model of integration with an iterative, dialogic understanding of integration (p. 223). By 2001, when Newell used her 1990 model as one starting point in his own theorizing (Newell 2001), Klein (2001) responded thus:

> Some time ago, I moved beyond this [1990] description….*The new model is a socio-linguistic conceptualization of managing complex problems*….The earlier descriptive steps reappear, but they are extended and recontextualized in an iterative model of communicative action in the dynamics of data, information, knowledge, intuition and insight, judgment, retrospection, and decision making. In a subsequent proposal for a generic model of integrative process, I retained the fundamental dialogical coexistence of differentiation and unity (Klein, 1996, pp. 222-224; 1990-1991). (p. 53, emphasis added)

Klein has continued developing this socio-linguistic model ever since, working to place interdisciplinary integration in its contexts. Together, her writings reveal a coherent view of integration as involving instances of socio-linguistic practice subject only to guiding principles, never mechanistic

rules. Figure 1 illustrates how this view hangs together as successively more specific (narrower) theories, and the next sections of this article describe the relationships between the levels.

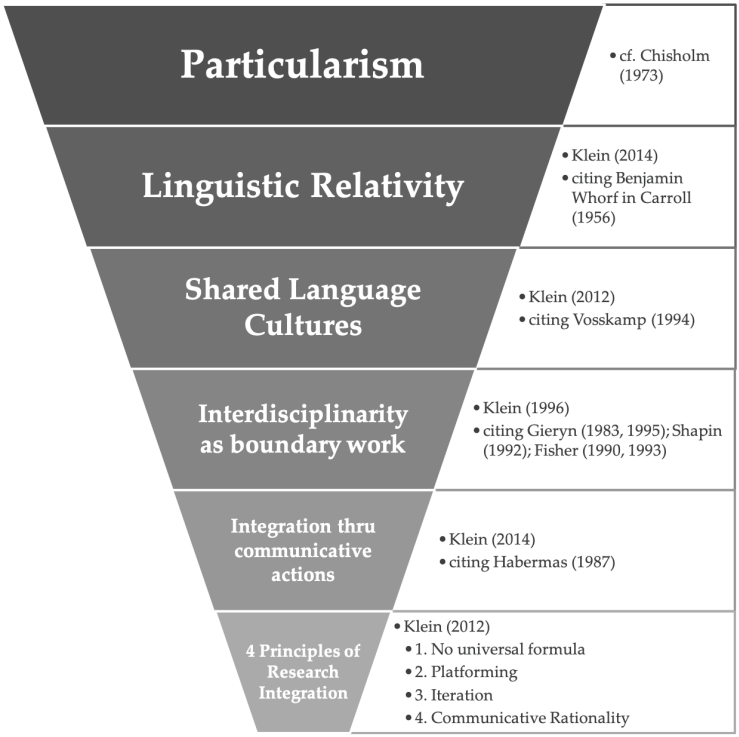


*Figure 1.* Klein's layered approach to understanding cross-disciplinary integration as a socio-linguistic phenomenon. Her approach proceeds from a more encompassing epistemology of particularism to a narrower theory of research integration. The citations for each level document the provenance of Klein's ideas as she cited them.

*Particularism*

Although she does not explicitly say so, Klein's fundamental approach to understanding integration is to study particular instances of it and then infer general principles from them. This bottom-up approach to defining a phenomenon, known as *particularism* (Chisholm, 1973), places more confidence in one's ability to recognize integration when one sees it than in

defining it without exemplars. This approach is why much of Klein's work involves intellectual history rather than, say, set theory. These recountings are not merely interesting; they are, in fact, the source of her insights.

*Linguistic Relativity*

From her observations, Klein – as a trained rhetorician and literature scholar – notices the importance of language in interdisciplinary practice. She finds this observation summarized profoundly in the concept of linguistic relativity. In Klein (2014), she explains,

> The concept of linguistic relativity is central to understanding interdisciplinary communication….The core premise is that language shapes the ways speakers conceptualize their worldviews, including the ways they think (cognition) and act (behavior). (p.15)

Linguistic relativity is an organizing concept that allows Klein to understand disciplines further as shared language cultures, not just worldviews or communities of practice.

*Shared Language Cultures*

If language shapes worldviews, and if worldviews go on to influence thoughts and actions, and if thoughts and actions are central parts of culture, then language is a key driver of a group's culture. It is, in addition, a key constituent of culture in its own right. In the language-as-culture view, disciplines are shared language cultures insofar as members understand each other through language. In fact, Klein (2012) claims, "The quality of [interdisciplinary] outcomes…cannot be separated from development and richness of a shared language culture" (p. 295). When people share a language culture, they can coordinate their insights and actions. This coordination enforces borders around the group that make interdisciplinary integration a matter of crossing the boundaries of disciplinary language cultures.

*Interdisciplinarity as Boundary Work*

Klein dedicated her entire 1996 book, *Crossing Boundaries: Knowledge, Disciplinarities, and Interdisciplinarities,* to explaining interdisciplinarity as boundary work. This article is too short to recount, indeed, even outline, all the insights the book contains, but we can summarize an important lesson thus: Just as there are many ways to interact across ethnic cultures, there are many ways to interact across disciplinary cultures, and all of these require

language in some way. Direct communication typically requires language, and so does coordinated action, such as deciding whom to ask for permission to use a lab's data by understanding what those researchers mean by terms like "principle investigator" and "data manager."

*Integration through Communicative Actions*

Because interdisciplinary work is intercultural language work, interdisciplinarity is a form of communicative action. In developing this thought, Klein draws on the work of Jürgen Habermas, who emphasizes that communication is neither rational nor productive when people do not share a language culture (Habermas, 1985, pp. 9-17, 86, 94-101). Habermas asserts that rational, productive communication must be "transsubjective" (Habermas, 1985, p. 9) or, alternatively, "intersubjective." Simply put, for integration to occur, people need to understand each other. Integration, in this view, consists of the many "trades" or communicative transactions in the trading zones (Galison, 1997) between disciplines. Because each disciplinary culture and each meeting of these cultures is different, the socio-linguistic model of integration, influenced by Klein's reading of Habermas, remains a high-level heuristic of interdisciplinary integration, and it emphasizes the actions of knowers rather than the products of knowledge they create. This cultural view of integration depends so much upon situation-specific interactions that it thwarts attempts to align it with Klein's 1990 stepwise model – even though that model was meant to be iterative and situation-specific. Instead of inviting a stepwise summary, Klein's more recent socio-linguistic model is best summarized as involving principles that act "more like guidelines than actual rules."[1]

*The Four Principles of Research Integration*

Klein (2012) summarizes the general characteristics of her socio-linguistic view of integration with the help of the following four principles:

1. "The Principle of Variance: No Universal Formula for Integration." (p. 293)
2. "The Principle of Platforming: Interaction Structure, Integration Potential, Fundament." (p. 294)
3. "The Principle of Iteration: Moving Back and Forth, Bootstrapping, Triangulation, Reflective Balance, and Weaving." (pp. 294-295)
4. "The Principle of Communicative Rationality: Shared Language

[1] To echo Blackbeard the Pirate, another famous thinker who operated at cultural boundaries (Bruckheimer & Verbinski, 2003).

> Culture, Social Learning, Translation-Negotiation-Mediation, Intersubjectivity." (p. 295)

Each principle derives from Klein's approach to interdisciplinary integration as illustrated in Figure 1 – from her particularism (Principle 1: Variance), to her view of integration as language cultures meeting in trading zones (Principle 2: Platforming), to her recognition of the messiness of intercultural boundary work (Principle 3: Iteration), to her commitment to intersubjectivity (Principle 4: Communicative Rationality). In what remains of this section of our article, we consider each of these principles in turn.

*The Principle of Variance*. Klein develops the Principle of Variance by observing that cross-disciplinary research projects vary along many dimensions, including context, focus, goals, participants, and scope. This variance implies that no universal formula of integration can account for all of the variables that figure into interdisciplinary and transdisciplinary research, and since such an accounting would be required of such a formula, no universal formula for integration can exist. We wonder, however, what she means when she denies the existence of a universal formula: Does she mean to deny possibility or just feasibility? The stronger version of the Principle of Variance would hold there is no *possible* universal formula for cross-disciplinary integration. A weaker version of this principle might be that there is no one *workable* or *tractable* formula, that is, no single formula that we could realistically and practically use to guide deliberation and action across the full range of interdisciplinary and transdisciplinary research projects. As we argue below, whether or not you agree with this principle may depend on the level at which you are conceiving of integration. We will argue below that there is a universal formula if you are conceiving of it at a very high, abstract level, but that this is not the case if you are conceiving of it at a lower, more concrete level.

*The Principle of Platforming*. This principle highlights the importance of "a set of actions aimed at building a foundation for integration"; for collaborative projects, this means "putting into place the antecedent conditions and contextual factors" required for epistemic and social integration (Klein, 2012, p. 294). Klein develops this principle by highlighting the structure of a project, both in terms of its timeline and its parts, including subprojects. This structure supports interaction among the parts of a project, including the people involved, as well.

This principle focuses on *project structure*, which we can take to be a systematic set of relationships among project elements. Within an interdisciplinary or transdisciplinary project, each element should be understood

partly in terms of its "integration potential" (Klein, 2012, p. 294), that is, its ability to contribute to the integration required for project success. Klein distinguishes those elements that are essentially integrative, for example, *bridge concepts* and *common foci*, from other elements (e.g., research questions, methods, disciplines represented) that may have more or less integrative potential, depending on the specific project context. Further, she introduces the notion of *interaction structure* to highlight that part of project structure that frames the contact among the different elements and creates the possibility of integration.

One important message entailed by this principle is that social and epistemic integration can happen at any time and any place in a project. That is, almost any location in a complex, cross-disciplinary project can be a site for integration. This widespread potential should not be surprising in light of the Principle of Variance. After all, if integration is sensitive to the great variability of interdisciplinary and transdisciplinary projects, this variability should include the various times and places integration might occur in a project.

*The Principle of Iteration*. The third principle emphasizes that the process of integration is not an uninterrupted, linear progression from unintegrated to integrated; rather, it can unfold in complex ways from more integrated to less integrated and back, or from interdisciplinary whole to disciplinary part and back. As Klein (2012) puts it, "These movements emphasize the importance of patterning and testing throughout the research process" (p. 295). Such "patterning" and "testing" are iterative reconsiderations that should track changes in understanding, objectives, and circumstances. This principle highlights the dynamic complexity of integration when it is a process platformed by certain elements in the project structure that vary along many dimensions. Following her own earlier work and that of Boix Mansilla (2010), Klein emphasizes *balance* in connection with this principle. That is, iteration keeps the many elements of the project in productive and not destructive tension.

*The Principle of Communicative Rationality.* The fourth principle articulates the importance of communication to integrative outcomes, especially when those are pursued by groups of collaborators. Klein (2012) illuminates how epistemic and social integration interact as collaborators communicate in moving toward intersubjectivity or "making sense together" (p. 295). Integrative communication requires "mediation" among different perspectives (p. 296). Mediating communication supports both reflexivity and perspective taking, creating the capacity for collaborators to achieve mutual understanding. Such communication encourages the progressive sharing of

"meanings, diagnoses, and objectives" (p. 296), and this progressive sharing is what creates intersubjectivity. Misunderstanding is always a risk in interdisciplinary contexts, but this can be mitigated by the creation and maintenance of a shared language culture that makes interdisciplinary dialogue possible. Although this principle acknowledges the roles of both epistemic and social elements in interdisciplinary integration, it foregrounds the social elements and reminds us how central communication is to integration.

In summary, the four principles bring out various aspects of integration as a process, highlighting among other things inputs (e.g., mediating communication) and outputs (e.g., mutual understanding) of the process. "The process," Klein (2012) tells us, "is not algorithmic. It is heuristic and constructivist at heart" (p. 296). The principles are also interrelated. For example, one might take the Principle of Variance to highlight the elements that figure into a specification of the process, the Principles of Platforming and Iteration the structural and functional aspects of the process, and the Principle of Communicative Rationality the role that people play in generating integrative outcomes.

## The IPO Model of Cross-Disciplinary Integration

If we as authors are to think with Klein about integration, it will help to be clear about our own way of thinking, which is the view of interdisciplinary integration developed in O'Rourke, Crowley, and Gonnerman (2016). This is an input-process-output (IPO) model that highlights the importance of integration as a *process* while still making room for understanding it as a *product* (i.e., as the *output* of the integrative process). In this section of our article we articulate this view, a view that has been influenced by Klein's work, especially Klein (1990) and Klein (2012). We describe the view in some detail here for purposes of comparing it with Klein's views, drawing out ways in which her ideas align with the IPO model and also ways in which the IPO model contrasts with her ideas.

O'Rourke et al. (2016) provide a theoretical account of what the authors call "cross-disciplinary integration," which is integration as it appears in the full range of complex activities that involve combination of disciplinary elements, e.g., multidisciplinarity, interdisciplinarity, and transdisciplinarity. To account for cross-disciplinary integration, they develop a model of integration in general. As they understand it, *integration* is a process that produces outputs that are typically different from and fewer in number than the inputs, where this reduction is a result of the process. This reduction is of course to be expected given that they take integration to be the combination

of elements into a whole (p. 67). Further, the processing involved typically puts the input elements into mutual dependence (cf. Andersen & Wagenknecht, 2013), where the contribution of a particular input to the output will depend in some (potentially complex) way upon its relationship with other inputs. (This typical impact of the process on the inputs rules out, by the way, the possibility of deleting one of the inputs as a means to integration.)

Three considerations serve as the basis for this account of integration. The first is the observation that people speak of "integration" in many different contexts even beyond cross-disciplinarity, such as art, politics, psychology, biology, and philosophy. Although in many of these contexts the term has a technical gloss, there is a core meaning that is part of common parlance. One aim of the IPO account of integration in O'Rourke et al. (2016) is to provide a *general* model of these different occurrences of the term and its cognates, subsuming them all under an abstract characterization of the concept. According to this approach, interdisciplinary integration is an instance, itself general, of a more general and widely-found process, where the specific properties of this instance are tied to the social and epistemic attributes of interdisciplinary activity. One important virtue of the general theoretical approach is that it supports the systematic transfer of insights about integration from one integrative context to another.

A conceptual model of the sort presented by O'Rourke and his colleagues (2016) could function simply to characterize logical connections at a general level, but the IPO model of integration is also intended to be specifiable so that it represents concrete integrative processes in specific contexts. As such, the IPO model is *schematic*, with abstract elements that are to be specified concretely when the model is applied in particular situations. These include the categories of *inputs*, *integrative relations,* and *outputs,* and parameters such as *commensurability, scale,* and *comprehensiveness*. In any particular instance, such as in a case of interdisciplinary integration, these categories and parameters will be specified in a way that renders the model more concrete. This rendering will involve quantitative aspects (e.g., the *number* of inputs) and qualitative aspects (e.g., the *types* of inputs).

The third consideration underlying the thinking of O'Rourke et al. (2016) concerns the role played by *integrative relations* in the model. Consistent with the idea that integration involves *combining* inputs into outputs, the IPO model of integration gives privilege of place to what it calls "integrative relations." So conceived, this can be understood as a *relational* model of integration, where the work of explaining integration involves identifying the characteristic features of integrative relations. Thus, the relational model aims to work out the details of step 3b in the Klein (1990) model, shining

light on the contents of the previously mentioned black box.

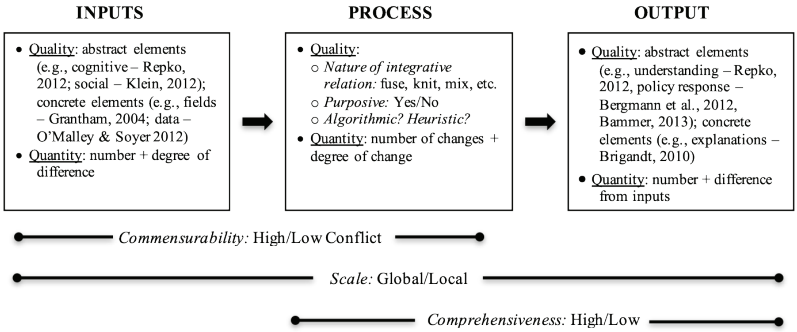


*Figure 2.* The specifiable but universal input-process-output (IPO) model of integration developed in O'Rourke et al. (2016) and pictured there on p. 69. The quality/quantity distinction classifies salient characteristics of inputs, processes, and outputs involved in episodes of integration.

The IPO model of integration is summarized in Figure 2, reprinted from O'Rourke et al. (2016). As noted above, it is an abstract, schematic model of integration that is intended to be rendered concrete through the specification of the variables that are built into the model. Using an IPO schema to model interdisciplinary integration requires identifying the inputs (e.g., a complex research question referencing multiple disciplines, researchers representing different disciplines if the project is collaborative), processes (e.g., collaboration, modeling), and outputs (e.g., published article with multiple authors, policy advice) that are relevant to the instance of integration under consideration.

The model is intended to represent integrative processes at different scales, and so in the interdisciplinary case it could represent integration that takes place over the lifecycle of a project as well as integration that takes place in a brief episode in which collaborators from different disciplines find a way to relate their alternative perspectives on a specific problem. The same model can be made to work at such different levels by specification of the values of the *scale* parameter – are we interested in integration at the more global, project-level scale or the more local, sense-making scale? The other parameters mentioned in Figure 2 also influence the nature of the integrative process: The *commensurability* parameter is set by the degree of difference that obtains

between inputs (e.g., low conflict between biochemistry and microbiology, high conflict between civil engineering and theater art), while the *comprehensibility* parameter corresponds to the extent to which the inputs are recoverable from the output (e.g., high comprehensiveness if input identity is lost in the integrative process, and low if input identity is retained).

The real action in this model takes place in the process box and involves the *integrative relations*. The integrating process puts inputs into these relations, thereby integrating them in generating the output. Not all relations are integrative. We can distinguish *integrative* relations from those that actively differentiate inputs – call these *disintegrative* relations – and those that leave inputs alone – call these *preservative* relations. Integrative relations change inputs by inducing dependencies among them, producing outputs that will typically (but not always) be fewer in number than the inputs. Disintegrative relations relate two things in a way that undermines existing dependencies, generating outputs that will typically be greater in number than the inputs. Preservative relations relate two things without changing them or inducing any dependencies that can reduce their number under the aspect of the output. Examples of integrative relations include blending (Nissani, 1995), extension (Newell, 2006), collaboration (Plutynski, 2013), and coupling (MacLeod & Nagatsu, 2016).

The IPO model of integration resembles other models that are available in the literature, for example, the idealized model of interdisciplinarity presented by deWachter (1982) and discussed in Klein (1990), and the model that is central to information integration theory, presented in detail in Anderson (1981).[2] Our interest in this article, though, is with the relationships between this model and Klein's views. While we will devote the next section to considering the relationship between the IPO model and the view developed in Klein (2012), we will close this section by considering its relationship with Klein (1990).

The stepwise model in Klein (1990) focuses on how one might engage in integrative activity from the initial phases to the final phase, providing

[2] DeWachter's (1982) model sets up interdisciplinarity as an IPO, with the process of integration black-boxed in the fifth stage, where in response to a global, interdisciplinary question, one "integrates all particular answers available" (p. 280). Anderson's (1981) account is more formal, detailed, and general. Information integration theory concerns how people combine information in making judgments, and Anderson's model of this type of integration is also an IPO model, with an emphasis on functional integration. Information integration theory depends on algebraic models, including "additive, averaging, and subtractive models" (Anderson, 1970, p. 156). In emphasizing relations, the IPO model in O'Rourke et al. (2016) is quite similar to Anderson's, but it is not limited to algebraic integration functions. This is not the place to develop a robust comparison of these two views, however.

people with guidance as they engage in interdisciplinary integration. In that sense, it is a *normative* model – it supplies a standard set of steps that, if executed, should result in integrative success. The IPO model, though, is descriptive, and is less focused on the full arc of an integrative activity than it is on the integrative episodes within that activity. Recall that the stepwise model in Klein (1990) includes a number of steps meant to ensure the preconditions for integration and the infrastructure necessary for integrative activity. The IPO model, by contrast, focuses on the moment when the inputs are brought together into integrated combination – the *process* box is the key location of this model. It seeks to show schematically (and, when specified, concretely and in detail) what must take place for integrative combination to occur.

**Comparing the IPO and Socio-Linguistic Models**

In this section, we compare the IPO model of integration developed in O'Rourke et al. (2016) and the socio-linguistic model of Klein, represented in summary by the four principles that conclude Klein (2012), discussed above. The IPO model is similar in a number of ways to the view that emerges from Klein (2012), in that both emphasize integration as a process that varies according to inputs, process characteristics, and outputs. In fact, Klein's socio-linguistic model served as an important influence on O'Rourke et al. (2016), as is explicitly acknowledged therein. Here we dive deeper into the similarities and differences among the two models so we can then show how they complement each other. (See Table 1 at the end of this section for a summary.)

In considering similarities and differences, we take Klein's four principles to be our guides. We begin with the Principle of Variance. One of the main motivations behind the IPO model in O'Rourke et al. (2016) is the variability of integrative processes, which range across a wide variety of phenomena and not just interdisciplinary or transdisciplinary activity. O'Rourke and his colleagues emphasize integration as a means to accommodate the manifold variability that Klein notes under this principle. The IPO model is intended to be universal in the sense that it applies across all contexts where one might find integration, although it is schematic and must be loaded contextually to model any specific instance. So, in a sense, O'Rourke and his colleagues both disagree and agree with Klein – there is a level of abstraction at which one can find a formula that subsumes all instances of integration, but also there is no maximally specific formula that applies to all particular instances of integration.

Klein's Principle of Platforming emphasizes the importance of thinking about integration at all points in an interdisciplinary or transdisciplinary project. The IPO model can represent integrative processes at various levels and temporal locations in interdisciplinary research. As those pursuing a project adjust the inputs involved, the various integrative relations that are a central part of the integrative process, and the scale parameter, which can be set globally or more locally, contextually loaded instances of the model can represent high-level integration (e.g., integration that results in the production of a new field, cf. Bechtel, 1993) or lower-level integration (e.g., at the level of data, cf. Leonelli, 2013).

The contextual flexibility of the IPO model also enables it to do justice to Klein's Principle of Iteration. There is nothing that keeps the IPO model from being instantiated in specific contexts that are brief and local, and there is no reason why it cannot be used in sequence to model a series of integrative episodes. Again, adjustments of variables and parameters make it possible to capture the iterative nature of project integration designed to strike a balance among different project elements.

Finally, the IPO model can be used to represent the processes of making sense together and building intersubjectivity and mutual understanding through both instrumental and relational communication (Hall & O'Rourke, 2014). These are social processes that involve epistemic elements in a central role, but the IPO model is designed to accommodate both epistemic and social integration, among other forms. Klein's development of the Principle of Communicative Rationality highlights the importance of a "shared language culture" to the mediation of information and relationships required to achieve integrative objectives in interdisciplinary and transdisciplinary projects. As introduced in O'Rourke et al. (2016), the IPO model would have difficulty representing this; however, there was no suggestion that the three parameters introduced in 2016 are the only relevant parameters. For instance, in accordance with Klein's argument concerning shared language cultures, the IPO model could include something like a *medium* parameter that concerns the medium in which communication takes place during collaborative instances of the use of the IPO model.

In sum, Klein's four principles either articulate aspects of integration that are important to the IPO model in O'Rourke et al. (2016) or phenomena that are critical to its implementation in a particular project. In our view, the IPO model and the socio-linguistic model are interrelated: On the one hand, something like the IPO model is presupposed by Klein's principles; on the other, Klein's principles and the socio-linguistic model they articulate are crucial to specifying the IPO model when it is used to describe cross-disci-

plinary integration. We exemplify this interdependence in the next section of this article by using both models to analyze a key form of cross-disciplinary integration – collaborative, interdisciplinary reasoning (Laursen, 2018a).

| Principle | Socio-Linguistic Model | IPO Model |
|---|---|---|
| 1. Variance | Particularism shows every trading zone between language cultures requires different boundary work. | There is a universal IPO formula at a high level of abstraction, but no universal formula at the level of particular instances of integration. |
| 2. Platforming | We need to be prepared to create these trading zones at any stage or level of an interdisciplinary project. | The IPO model can apply to integration at any stage or level in an interdisciplinary project. |
| 3. Iteration | The boundary work required for interdisciplinary balance is not typically one-and-done, but is rather iterative and complex. | The IPO model can represent iterations and the complex ways in which integration manifests in interdisciplinary projects. |
| 4. Communicative Rationality | Shared understanding through language is necessary. | Communicative integration can be represented by the IPO model, although it may need a new parameter to reflect shared language culture. |

*Table 1.* A summary of the relationships between Klein (2012)'s four principles of integration and the input-process-output (IPO) model of O'Rourke et al. (2016).

## Integrating the Models of Integration: A Worked Example

The IPO model aims to characterize integration in general, while Klein's socio-linguistic model describes cross-disciplinary integration. As described above, Klein's model presupposes something like the IPO model, and the two models are therefore compatible. In this section, we argue by example that the models are more than compatible – they are complementary. As such, they are more useful together than apart in describing instances of cross-disciplinary integration. Our example is a thread of collaborative, interdisciplinary reasoning excerpted from a Toolbox workshop transcript (cf. O'Rourke & Crowley, 2013). The Toolbox Dialogue Initiative hosts dia-

logue-based workshops for cross-disciplinary and cross-functional teams.[3] These dialogues are semi-structured by prompts that articulate assumptions that researchers and professionals usually leave implicit in their work but that would likely derail their team if left implicit because not everyone on the team holds those assumptions. The prompts invite each participant to respond on a Likert scale of "Strongly Disagree" to "Strongly Agree"; "Neither agree nor disagree," "I don't know," and "N/A" are also options. However, the prompts are worded with vague and sometimes extreme language that requires participants to define their terms or express qualifications in order to respond. These definitions and qualifications reveal hidden assumptions, making them available for discussion. Participants respond to all of the prompts first in writing on their own. Then, participants discuss their responses, and usually participants are invited to re-take the instrument to see if their views have changed.

We draw on Laursen (2018a) to show how instances of collaborative, interdisciplinary reasoning such as the Toolbox workshop below can be characterized as argumentation. This example will show that argumentation is one of the socio-linguistic routes to cross-disciplinary integration, and that it and similar routes stand to benefit from a dual application of the IPO and socio-linguistic models. This example also shows how the fields of argumentation and interdisciplinarity enlighten each other, as proposed in Laursen (2018b), published in this journal last year.

**Example**

In this example, a cross-disciplinary research group is mid-way through their 90-minute dialogue session. They've discussed several prompts already. Now they are discussing two prompts about reductionism vs. emergentism. First, they discuss Prompt 30: "The world under investigation is fully explicable as the assembly of its constituent parts." Participants 1 and 3 (P1 and P3) disagree with this statement, but P2 doesn't know because they can see it both ways:

[3] http://tdi.msu.edu

| Speaking Turn | Utterance |
|---|---|
| 203 | P2: I didn't know. I think when you talk about an assembly of things, yes they are constituent parts but they're assembled and so they're still connected. Sometimes you have to reduce it into smaller systems so you can comprehend and make quantitative answers and then you're always looking at, well I guess I never see it as one of these systems is totally independent from all of its connected parts. So this huge system and everything that we're looking at can always be taken into more systems or more parts and is always connected to other things. |

The group then turns to the next prompt, Prompt 31, which reads, "The world under investigation must be explained in terms of the emergent properties arising from the interactions of its individual components." After reporting their agree/disagree scores to each other, Participants 1 and 2 (P1 and P2) discover they both agree.

| Speaking Turn | Utterance |
|---|---|
| 210 | P1/P3: Woah! [laughter] |
| 211 | P1: We haven't agreed this whole time! I strongly agreed with that statement and I think it's my training and my background honestly that encourage me to say that because for example I remember from my introductory ecology class I took in college, the first day it was like the quote up on the PowerPoint slide was "the sum is more than all the parts" or whatever that statement is that says that essentially. |
| 212 | P2: I see how this is supposed to be kind of a converse of the previous statement but I interpreted it somewhat the same in terms of if you can't always understand the individual components it's kind of hard to explain the interactions as well but yeah I probably went a little farther than I would on [my own] on that one. I was thinking "fully" explained I guess, but that word wasn't in this one. |
| 213 | P3: Yeah I think to look at anything you have to simplify it somehow in your head so that you can understand it and then from the simplifications you then bring them back together. |

| | |
|---|---|
| 214 | P1: And things arise that you probably wouldn't have seen just by looking at the individual components. And that's how I interpret emergent properties anyways. |

In some respects, Prompts 30 and 31 are opposite and one would expect a participant who agrees with one to disagree with the other. However, P2 doesn't; while they are uncertain about reductionism they agree with emergentism. If we just looked at the scores, we might think P2 isn't reading the prompts carefully or lacks introspection skills. But the transcript tells a different story, showing that P2 holds a nuanced view that integrates aspects of both reductionism and emergentism, and this was hard to represent through responses to the prompts as written.

In the discussion, P2 explains how emergent explanations depend on identifying the parts in order to track the interactions between those parts. P2 indicates that they interpret Prompts 30 and 31 as "somewhat the same," which signals emphasis on the role played in both by the need to "understand the individual components" and on the fact that both prompts require the individual components to be related to one another – *assembled* in Prompt 30 and *interacting* in Prompt 31. Another way to look at this, articulated in ST 203 and reflected in ST 212, is that when it comes to complex systems, one needs to be willing to look at smaller and smaller parts in order to understand the whole, where this involves individual components at bottom. The difference in P2's reaction – scoring an "I don't know" to 30 and a "Strongly Agree" to 31 – is explained by the appearance of the word "fully" in 30 but not in 31. Collaborative reasoning with P2 moves P1 and P3 to acknowledge that it *is* important to pay attention to the parts of the world under investigation, including the individual components, even if one is a staunch emergentist.

It is clear this discussion thread contains some argumentation because claims and reasons are being exchanged, evaluated, and modified. In fact, the participants are eventually willing to entertain the nuanced position – championed by P2 – that reductionism and emergentism are not so obviously contradictory. The claimed similarity between the views is even clearer if we schematize the argument that emerges from P2's comments in standard form.

> *Premise 1.* According to reductionism, if one doesn't understand the parts of complex systems (e.g., subsystems, individual components), then one cannot explain assemblies of those parts. (ST 203)

*Premise 2*. According to emergentism, if one doesn't understand the parts of complex systems, one cannot explain interactions of those parts. (ST 212)
*Premise 3*. According to reductionism, if one explains the parts of a complex system in relation to one another, then one explains assemblies of parts. (Implicit)
*Premise 4*. According to emergentism, if one explains the parts of a complex system in relation to one another, then one explains interactions of parts. (Implicit)
*5*. According to both reductionism and emergentism, if one explains the parts of complex systems in relation to one another, then one must understand the parts. (From P1, P2, P3, P4)
*Premise 6*. If one fully explains a complex system, then one explains the parts of the complex system in relation to one another. (Implicit)

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*Conclusion*. Reductionism and emergentism both require an understanding of the parts to explain a complex system. (5, P6)

Thus, P2 has integrated reductionism and emergentism by asserting that they share a commitment to understanding the parts of complex systems. Now we will show that if we analyze this integration episode with both Klein's socio-linguistic model and the IPO model, we can more fully explain the integration happening here than if we rely solely upon one model or the other.

**Analysis of the Example with Both Models**

With regard to Klein's model, the following things are important to note here. First, this is not the only way to synthesize reductionism and emergentism. According to Principle 1: Variance, we ought not to expect this team to synthesize other inputs in this way in other episodes. In fact, this same team might synthesize the same theories in a different way later in their project or even in this workshop itself. In addition, we should not expect other teams to synthesize these two explanatory theories in just this way either. Second, this synthesis relies upon a foundation laid by the structure of the Toolbox prompts themselves, which have asked participants to discuss their views on reductionism and emergentism. According to Principle 2: Platforming, "common foci" such as these prompts are a "fundament" or

"interaction structure" for integration, enabling collaborators to focus on the same[4] research object to begin integrating their insights about it. Third, this conversation highlights the "patterning and testing" that are crucial to Principle 3: Iteration. In this part of the dialogue, P2 stands out as someone with a different opinion, testing alternative ways of thinking about Prompts 30 and 31. By ST 214, the initial disagreement and difference among the collaborators give way to a kind of balance (cf. Boix Mansilla, 2010). Fourth, integration requires a language culture that is shared to some extent, and integration, in turn, enhances this shared language culture. In this case, the prompts have provided shared language, and the collaborators work through the episode to coordinate their understanding of these prompts and come around to a shared way of thinking about them. According to Principle 4: Communicative Rationality, integration both requires and builds a shared language culture because this is what enables collaborators to understand, evaluate, and respond to each others' proposals.

If we are to use the IPO model to explain the integration here, we must identify the inputs and outputs of this integrative episode, as well as the integrative relation(s) used to transform the inputs into the outputs. If we focus on the content of the dialogue, that is, the *argument*, as opposed to the arguers, then the standard form helps us locate inputs and outputs; specifically, the inputs consist of the premises and the integrated outputs are the conclusions (i.e., intermediate step 5 and final Conclusion). The argument establishes that reductionism and emergentism share an interest in the same thing: the parts of a complex system. In effect, then, the integration here is subsumption of two ostensibly inconsistent theoretical views under a single category (viz., theories interested in parts of complex systems). This subsumption under a common category explains why P2 believes that Prompt 30 and Prompt 31 are "somewhat the same" (ST 212).

From a rhetorical view, looking now at the *arguers*, we can take the inputs to be the social elements that are introduced into this exchange, such as the collaborators themselves, and take the outputs to include acknowledgement on the part of P1 and P3 that there is something to P2's complex view. The processes that transform these rhetorical inputs to outputs include social processes (e.g., trust-building through mutual enjoyment and use of the first-person pronoun, empathizing, acknowledgment) and cognitive processes (e.g., perspective-taking, explanation, illustration, collaborative reasoning). The integrative relations key to these processes from a social

[4] Here, "same" does not mean everyone must understand the research object the same way. In fact, if they did, this would be the opposite of a platform for integration as there would be nothing to integrate – only sameness. Rather, "same" means "shared" as with a boundary object or bridging concept (Klein, 2012).

perspective could include recognition, greater trust, and enhanced team cohesion. In both the argument case and the arguer case, the IPO model also asks us to be explicit about the commensurability of the inputs (high), scale of the integration (local), and comprehensiveness of the entire episode (low, in the sense that we can recover the inputs in both cases).

It is clear, then, that the socio-linguistic and IPO models of integration give different but compatible views of the same episode. But they are not merely compatible – they are complementary. Klein's socio-linguistic model identifies what types of inputs, processes, and outputs are possible by articulating what led up to and is likely to follow from the integrative episode, while the IPO model structures and parameterizes these components. In instances of collaborative, interdisciplinary reasoning such as our example above, Klein's socio-linguistic model tells us to look for shared standards of reasoning and both logical/epistemic and social/rhetorical argumentation moves. The IPO model asks us to get specific about which elements, standards, and moves are being used as the integrative inputs, processes, and outputs (not necessarily respectively). Perhaps most importantly, the IPO model spotlights the integrative relation(s) deployed in the argumentation.

## Conclusion

In conclusion, the IPO model is a general framework for integration intended to capture integration in any context, whereas Klein's socio-linguistic model is really focused on cross-disciplinary integration; as such, the latter could be used to help guide instantiation of the IPO model in particular cross-disciplinary cases. With such a stereoscopic view of collaborative, interdisciplinary reasoning, new explanations of integration become possible. For example, we can use argumentative examples like the Toolbox excerpt above to identify a range (and perhaps a typology or taxonomy) of integrative relations used by collaborators when speaking with one another or collectively to the outside world. We can also investigate the inputs, processes, and outputs that collaborators are using to integrate socially, such as using language to build team cohesion. Lastly, we can explore the feasibility of specifying the parameters in the universal IPO model into workable, situation-specific "formulas."

But, we hasten to conclude that in many respects, the foundation of an idea is more important than its future prospects since there can be no advancement without a beginning. Julie Thompson Klein's work on integration has been foundational for us. As we have shown, the IPO model, integrative relations, and integration through argumentation are all rooted in Klein's work

on interdisciplinary integration, and we expect many other contributors to the literature on integration will find her work to be fertile soil for their own work, as well.

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