The Primary Interactive Pathway: An Analytic Tool For Examining and Comparing Students' Representational Activities

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Visual representations, such as drawings, graphs, and computer simulations, allow humans to accomplish truly incredible tasks by supporting the storage, organization, comparison, and movement of complex information (Latour, 1988). For this reason, representations have long been considered central both to professional science (Latour, 1987; Lynch, 1988) and to science education (c.f., DiSessa & Sherin, 2000; White, 1998). Therefore, a great deal of research has been conducted to understand the affordances of particular representations in problem solving and learning (c.f., Suthers, 2001). Unfortunately, much of this research ignores the fact that the classroom or the scientific community use representations in particular ways and the representations mean little outside of these situated contexts. To understand this intersection between students' representational actions, their local context, and community norms, it behooves us to examine representations as a form of social practice or activity (Danish & Enyedy, 2007; Hall, 1996; Roth & McGinn, 1998). The proposed paper aims to advance the field in two key ways. First, I suggest an analytical framework, the *Primary Interactive Pathway* (PIP), as an approach to examining and comparing different activity contexts in terms of their role in shaping students' engagement with representations. Second, I present empirical data regarding the role of activity contexts in shaping how kindergarten and first grade students engage with representations.

Background and Theoretical framework

Why young children?

Ongoing success in science learning requires building on representations and associated practices which students are presumed to have learned throughout their schooling career. Without these practices, students have difficulty learning new representational forms as well as new scientific concepts that rely on representations (e.g., the concept of acceleration is typically taught using graphs to represent motion). It is therefore crucial that students begin learning to effectively use scientific representations as early as kindergarten and first grade. Furthermore, while kindergarten and first grade students typically have a great deal of experience representing their ideas through drawing before entering school, this experience does not always translate well to creating science representations. Kindergartners often omit important details from their drawings (Tversky, Kugelmass, & Winter, 1991), include details in ways that are unclear to others (Willats, 2005), or inadvertently apply rules that are appropriate when drawing for fun but not for science (DiSessa, 2004).

As students progress through school, their in- and out-of-school experiences help to shape the way that they engage with representations (Sherin, 2000). Thus, it behooves us to first understand the origins of students' engagement with representations early in their school careers and how this is influenced by their local context. This kind of genetic account (Wertsch, 1981) can then help us understand the representational practices of students of all ages, and the process through which they develop.

Activity Theory and the Expanded Mediational Triangle

I have chosen to ground my examination of students' representational actions in activity theory (M. Cole, 1996; Engeström, 1987) because of its utility in analyzing the influence of contextual factors upon students' representational actions. Activity theory identifies joint, mediated, object-oriented activity as the central unit of analysis for human activity. In particular, I will make use of the expanded mediational triangle (Engeström, 1987) as a tool for examining students' activities (see Figure 1 for an example triangle). The expanded mediational triangle depicts the key mediators of collective activity, as well as their relationships, specifically the fact that they are all connected.

At the top of the triangle we see the original mediational triangle that Vygotsky used to describe mediated action by an individual subject (M. Cole, 1996; M. Cole & Engeström, 1993). This triangle depicts the fact that the subject, which in the present study will represent a student, is engaged in some object of activity with the use of artifacts. The subject has access to the object both directly and indirectly via the artifacts. For example, if a student in the current study is creating a drawing using a pencil, they are using the pencil to add to the drawing, but can also see the drawing directly as they continue to draw it. This also highlights the fact that each connection in the triangle examines the flow of mediation in two directions, not just originating from the subject. Returning to our example, as a student creates the drawing, they are in turn influenced by what they see on the paper, including potential new relationships between features which may not have been apparent to them before placing them on the paper. In fact, the subject and object both change over time as the subject engages with the object and their conception of it is refined by experience (M. Cole & Engeström, 1993).

The bottom half of the triangle adds the community of people who have a shared object with the subject to Vygotsky's triangle. In the current study, this will most frequently represent the other students in the classroom. Finally, the rules and division of labor represent other mediators which help to determine the relationship between the subject, object, and community. For example, in the current study there was sometimes a rule that students need to ask their peers about the drawing they were creating. In those cases, the rule was dictating the interaction between the subject and the community, while the division of labor explains the different roles: one student asks the question, and the other offers an opinion.

Data sources, evidence, objects or materials

The present data comes from a participant observation of a 19-session (10-week) curriculum intervention to teach students about how honeybees collect nectar. The intervention took place with two mixed-age kindergarten and first grade classrooms in a progressive California elementary school. There were 42 students who consented to participate in the study (22 boys, 20 girls). The study as a whole is described elsewhere (Danish, 2009a, 2009b). The students in this study were organized into groups of 5 students, and rotated between through a variety of representational activities as they learned about honeybees collecting nectar. On each day of the study, two groups of students were videotaped as a case-study.

The current paper examines the differences between students engaging in individual creation of representations, participatory models, and participatory simulations. *Individual creation of representations* (Figure 1) refers to an activity, typical of kindergarten and first grade classrooms, in which students created individual drawings, sculptures, or collages while sitting at a table surrounded by peers with whom they were allowed to discuss their work. *Participatory modeling* (Figure 2) is an activity in which students worked collectively to use act out a model of the honeybees—essentially a short skit focused on conveying science content. *Participatory simulation* (Figure 3)(Colella, 2000) refers to a game-like activity in which the students played the role of honeybees that had to convey the location of nectar (small corks hidden around the schoolyard) to their peers as a way of experiencing the challenges that bees face.

Methods

Video records of students' interactions as they created representations in each activity were observed and analyzed to identify patterns in the relationship between the activity context, and students' discourse about their representations. Activity triangles were created to document the general pattern of activity, and the triangles were then modified as required by additional observation of the video record. Procedures borrowed from discourse analysis (Erickson, 2004) were then used to examine the relationship between the students, the representation they were creating, and the community within each activity.

The primary interactive pathway.

The expanded mediational triangle depicts the relationships between the subject (in this case a student), the object of the activity, and the multiple mediators of that activity (Engeström, 1987). The mediators include the community, rules, division of labor, and artifacts. Artifacts can be both material (i.e., pencils and drawing paper) and ideal (i.e., a shared understanding about how honeybees collect nectar). By definition, all mediators depicted within an expanded mediational triangle play a role in influencing the subject's actions as they engage with the object. However, when comparing multiple activity systems, it is helpful to restrict our analytic focus to a few key mediators in order to more easily identify the differences, particularly given that participants within an activity often selectively attend to certain features of that activity (Erickson, 2004; C. Goodwin, 2000; C. Goodwin & Goodwin, 1996; M. H. Goodwin, Goodwin, & Yaeger, 2002).

The primary interactive pathway is proposed as a means of focusing analytic attention on one set of relationships within the expanded mediational triangle by articulating those features of the ongoing activity that the participants appear to be explicitly attending to in their ongoing interaction. Specific attention is placed on highlighting the interaction between the subject and one specific mediator of interest in order to compare the relationship between the two across activity contexts. In the current study, the primary interactive pathway will describe the way in which students (as subjects) interact with, around, and while creating the primary representation (as the mediator) in pursuit of the object of their activity.

As its name suggests, the primary interactive pathway is intended to focus on participants' actions that are visible in interactions through talk and gesture. Students often make choices, such as where and how to draw aspects of honeybees that have no immediately visible cause or impact on their peers. However, using techniques from discourse analysis, it is possible to identify and trace the impact of students' actions in the sequential stream of talk and gesture as they engage in joint activity. The primary interactive pathway is, therefore, identified and exemplified by samples of student discourse, which includes talk, gesture, and the organization of space.

In order to identity the primary interactive pathway for analytic purposes, I started with the activity as designed and legitimized by the teachers. For example, if students were asked to create drawings of bees using pencils and paper, I began with the assumption that the students would primarily create drawings of bees using those pencils and paper. This primary interactive pathway is depicted as the bold line in Figure 1. Note that the other mediators are still included in the diagram, because the assumption is that they still play a role in mediating the students' actions, just not a consistently, visible, legitimized role. For example, other students might be present, but in a more supporting or secondary role, only occasionally offering feedback. Therefore, the community is not part of this particular primary interactive pathway.

Of course, students often engage in alternative activities, or counter-scripts within classroom activity (Gutierrez, Rymes, & Larson, 1995). I therefore examined the data for each activity to determine whether actions that did not appear to fit the primary interactive pathway represented either an alternative object that appeared to be pursued by students, or an exception that helped to clarify the role of the primary interactive pathway. In the current study, it was not necessary to revise the primary interactive pathways in response to this analysis.

The role of community vis-à-vis the students' primary interactive pathway is particularly relevant given my analytic focus on students' critical discourse related to their peers' representations. As I will show, the position of the community relative to the subjects' primary interactive pathway influences students' discussions about their representations, which in turn influences the kinds of representational choices that are made visible and discussed. For example, it appears that when students are working individually on drawings, their occasional feedback to each other focuses almost entirely on what aspects of the honeybees are present in the drawing. This is in contrast to students' work in creating participatory models where the organization of activity appears to encourage discussion about how to represent the bee.

I will argue that this difference in which aspects of the representation the students discuss is caused in part by whether or not the primary interactive pathway includes the community. In the case of creating individual representations, the community is not part of the primary interactive pathway because the students do not need to communicate with them to accomplish the object of their activity. However, occasional confusion may lead to their engagement with their peers. In contrast, participatory modeling requires the students to coordinate their actions with their peers to collaboratively create a representation, placing the community in the primary interactive pathway (see Figure 2 below). This kind of pattern in the relationship between the organization of activity and the topics of students' representational talk is what the primary interactive pathway is intended to make visible.

One final note on the role of the community in the primary interactive pathway is in order. Anytime that other members of the community are involved in activity, the rules and division of labor become meaningful as they describe that role in detail, articulating for example whether the community members serve as an audience, or collaborators in creating a representation. It would, therefore, be redundant to include these in the primary interactive pathway unless they become the explicit focus of the students' attention (for example, if the students were oriented toward defining and arguing about the rules of their interaction). Therefore, in the present analysis, while the rules and division of labor are identified as meaningful mediators of the students' activities, they have not been included in the primary interactive pathway, regardless of the role of the community.

The PIP serves not only to highlight the role of the representation, but also to document the interaction that was most visible in the video record. Ultimately, the PIP was a useful analytic framework for comparing activity contexts. For example, the PIP for creating individual representations (shown by the bolded line in Figure 1) shows that students primarily worked with pencil and paper to create their drawing, only interacting occasionally with their peers. In contrast, the PIP for participatory modeling (see Figure 2) reveals that the organization of the activity required the students to engage with their community as they were co-constructing a skit. Finally, patterns in how the PIP shifted the focus of students' talk as a proxy for their engagement with their representations were documented and are presented below. In particular, I identify whether students discussed *what* features the representation needed to include, *how* those features should be represented, or *why* the representations should either be included (or included in a particular way). The discussions of what, how, and why to create representations in particular ways suggest increasing levels of sophistication in the students' co-constructed analysis and critique of each other's representations.

Results

Figures 1-3 show the general pattern of representational activity that was observed across the three activity contexts. The differences between these activities are then summarized in table 1. Table 1 demonstrates the distinct differences both in what role the representation played in each form of activity and in the kind of discourse that was present as students engaged in these activities. Student dialogue varied from a focus primarily upon "what" to represent during individual creation of representations to the inclusion of "how" and "why" during participatory modeling and participatory simulation. For example, students' focus on the list of bee parts to include in their drawings, and the need to complete individual drawings, often resulted in only brief exchanges that consisted of reminding each other to include those features—the "what" conversations.

The first thing we notice in the table is the role of the primary representation. In some ways, this might seem like a telltale sign of whether or not two activities share a similar impact upon students' representational actions. One might expect that representations created as the object of a students activity—individual representations and participatory models—are likely to share something in common, particularly when compared to a representation that is created as an artifact in service of a larger activity (participatory simulations). However, this appears not to be the case, particularly when we examine the content of students' talk about their representations. Rather, individual creation of representations appears to be the unique case where the students primarily discussed what features to include in their representations.

In contrast, the participatory modeling and participatory simulation activities appear to share more in common, prompting the students to also discuss how and why to create their representations in a particular way. This similarity currently appears to be predicted by the role of the community in the primary interactive pathway. This makes intuitive sense as representation is a communicative act, and so the more that the students engaged in activities where they need to communicate with the community of their peers, the more they ultimately engaged with their community about the details of their representations. The importance of the organization of activity regarding the community was further supported by an analysis of some of the moments identified within the students' creation of individual representations, in which the students appeared to discuss the how of their representations. Specifically, those interactions appeared to occur when the students not only interacted with their peers, but when a impetus such as confusion between students led to a communicative breakdown, ultimately making the community more central to the students' ongoing actions as they attempted to resolve that breakdown.

Another way to look at this particular pattern is to examine the role of talk and gesture, as students' most familiar forms of communication, across the three activity contexts. If we look at individuals creating representations, participatory modeling, and participatory simulations as existing along a spectrum, creating individual representations is at one extreme, where students' ability to coordinate their actions and ideas using talk and gesture is a resource primarily used to resolve breakdowns. Participatory modeling is an activity where the use of talk and gesture is central, but not all interpretive breakdowns are easily identifiable. Participatory simulations, however, are a context where the breakdowns are immediately visible because they lead to unsuccessful completion of the joint activity. This suggests that those activities where students are best equipped to resolve a communicative breakdown are also those in which they are most likely to discuss the what, who, and why of their representation.

However, there are additional, potentially important distinctions hidden by this generalization, particularly when we compare the aspects of what and why that the students discussed across these three contexts. Students engaged in creating individual representations and participatory modeling were discussing science content when they talked about what to represent. In contrast, the students involved in creating instructions as part of the participatory simulation were discussing the location of a hidden object in their playground. Also, students discussing why to make certain representational choices during participatory modeling focused on issues such as visual fidelity to the referent, which in that case was the object of scientific study—the honeybee as it collected nectar. In contrast again, the students' reasons for their representational choices during the participatory simulation were more about the community itself, and their desire to have the game be fun, but also concluded in time to be able to go to "team time" and engage in other fun activities.

One gloss of these differences is the fact that the more familiar an activity context is in terms of talk and gesture, the less it is likely to lead to an examination of something new such as the science content. This is not to say that participatory simulation was a non-productive exercise, as the students who created the instructions and followed them appeared to express important insights into how to clarify one's representation, and into how bees are able to find nectar faster when they have instructions to the nectar source. Rather, those contexts in which communication is a more familiar medium for the students may lead to richer discussion about representations as a communicative tool, focusing on issues of how and why to represent a particular idea in a given way.

This kind of discourse about the how and why of representations is a potentially valuable for students as they create science representations. For example, re-visiting diSessa et al's (DiSessa, Hammer, Sherin, & Kolpakowski, 1991) work on meta-representational competence, it was exactly this kind of talk about issues such as the need for parsimony that pushed the students to revise their representation and ultimately create an approximation of graphing. Obviously, it's not just students' talk about representations. Other factors are involved including the students' understanding of the content, as well as the specific criteria that they do focus upon when discussing why to make certain representational choices. Fortunately, the findings of the current study, by suggesting patterns between the activity context and students' representational talk, also suggest opportunities for making these kinds of reasoning explicitly visible in students' interactions. For example, some students were quite explicit about the reasons behind their representational choices—to make the model look like a real flower—as well as their working understanding of the content which lead to these reasons—the nectar is on top of the flower. This in turn provided an opportunity for the other students and the teacher to ratify some of these choices and challenge others.

In sum, the different representational activities analyzed here each played a different role in supporting students in engaging in a particular kind of interaction around their representations. The concept of the primary interactive pathway, as a tool for comparing activity systems using the expanded mediational triangle appears to be a productive tool for helping to identify the constellation of features in each activity system that leads to these different patterns in students' interactions. Ultimately, it is a question of curriculum design which of these relationships is most effective at what time. There are certainly times in a curriculum when the teachers may want the students to focus on the necessary features to include in a particular representation. At other times, it may be beneficial to encourage students to focus on the reasons for including particular features in representations, particularly when those representations are created in the service of studying science content. Fortunately, it is clear from the current analysis that kindergarten and first graders are quite capable of engaging in each of these activities in a productive manner, discussing the what, how, and why of their representations.

Significance

The findings in this paper contribute two important advances to the study of students' representational activities in science classrooms. First, the PIP, coupled with discourse analysis, has proven a useful framework for using the expanded mediational triangle to compare and contrast diverse representational activities in terms of how they shape students' participation. Second, the data presented in this paper contributes to the body of knowledge regarding how our youngest students engage with representations. Contrary to popular wisdom, these young students are capable of much richer discussion than might be otherwise evident when they sit at tables creating individual drawings. The participatory modeling activity in particular demonstrates that a simple shift in the organization of activity can promote rich, scientifically valuable debate about science representations, even in kindergarten and first grade classrooms.

Tables and Figures

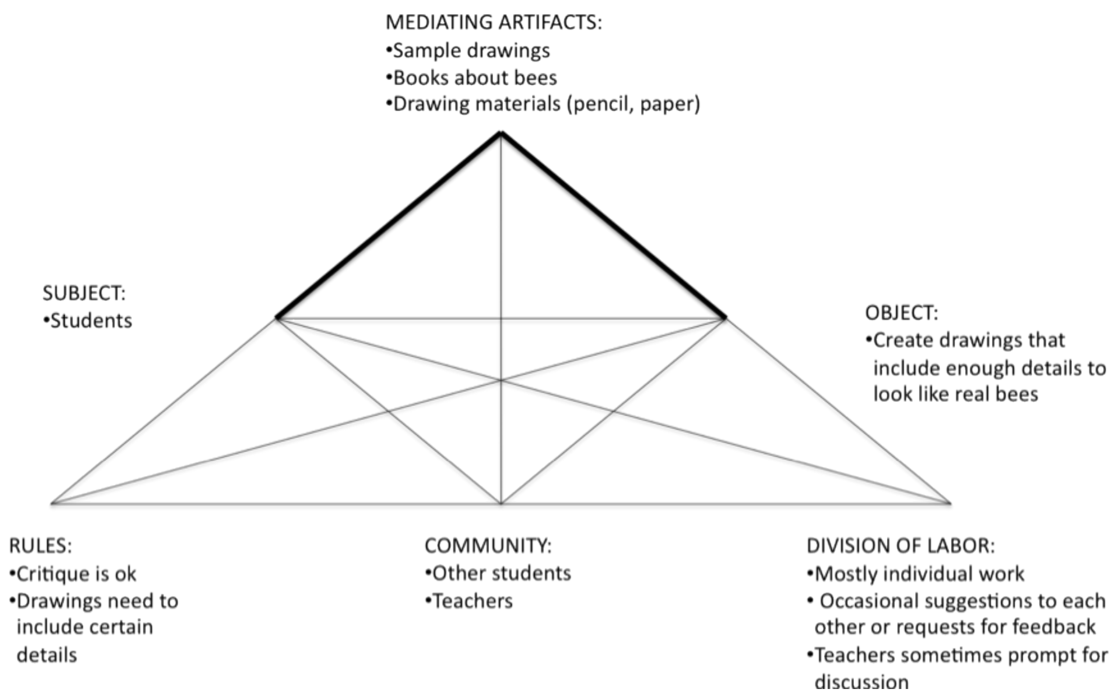

Figure 1: Creating Individual Representations (Based on Engestrom, 1987)

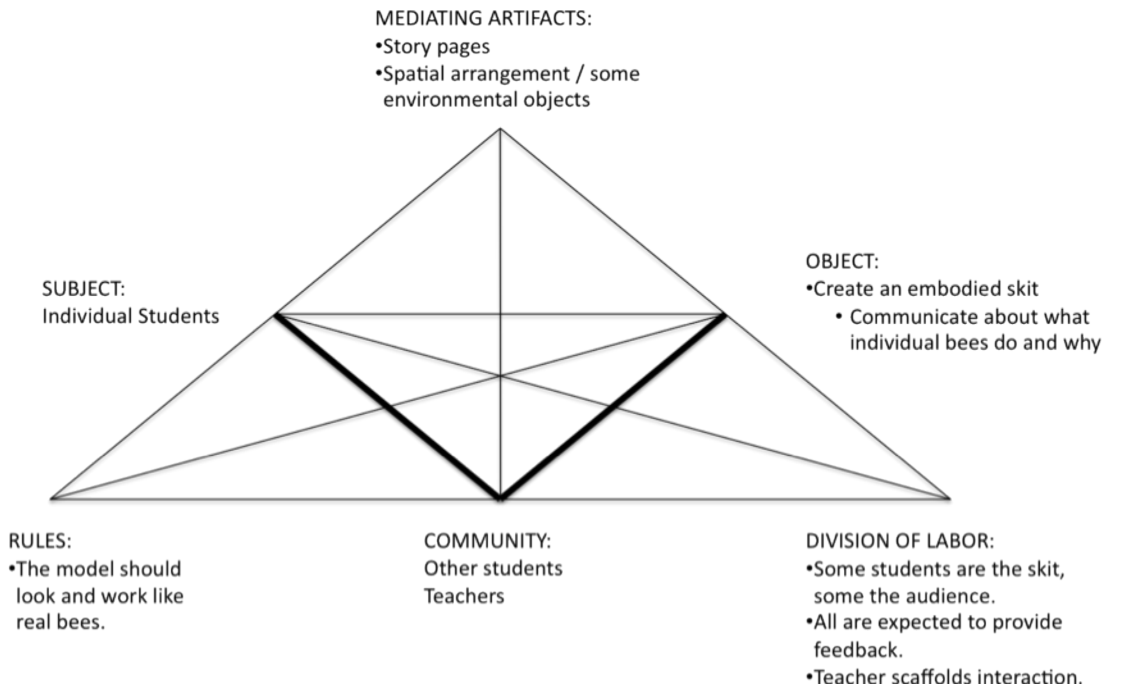

Figure 2: Participatory Modeling

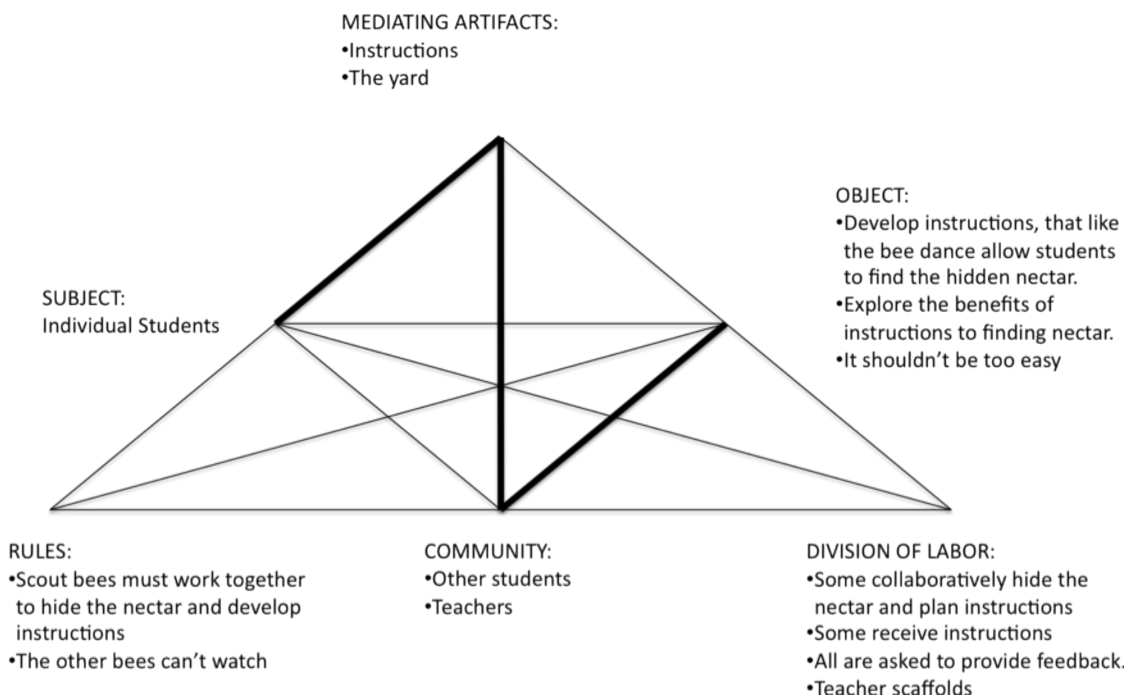

Figure 3: Participatory Simulation

Representational Activity	Primary representations as	Community within Primary Interactive Pathway	What, How, Why
Individual Creation of Representations	Object	No	What
Participatory Modeling	Object	Yes	What, How, Why Why related to implicit assumptions of science.
Instructions Created Within Participatory Simulations	Artifact	Yes	What, How, Why Why related to a number of issues regarding the community.

Table 1: Summary of the variations across activity contexts

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