BRILL

Journal of Cognition and Culture 13 (2013) 145–157

brill.com/jocc

Cultural Differences Between *Favela* and *Asfalto* in Complex Systems Thinking

Izabel Duarte Olson*
Northwestern University School of Education and Social Policy, Walter Annenberg Hall, 2120 Campus Drive, Northwestern University, Evanston, IL 60208, USA
*E-mail: izabel@u.northwestern.edu

Abstract
Favela residents in Brazil have been marginalized throughout their history. Nonetheless, the *favela* environment seems to create conditions conducive to a cognitive orientation that could be advantageous for engaging in complex systems thinking. This study is a preliminary examination of people from different social backgrounds in Rio de Janeiro, both *favela* (working-class) and *asfalto* (middle-class) dwellers, and evaluates whether their cognitive orientations might present any markers for the potential of complex systems thinking, including: (1) the ability to see multiple perspectives, and (2) a tendency to focus on relationships. I conducted a mixed methods research study based on in-depth interviews with 89 residents in Rio de Janeiro. The data indicate that *favela* residents in Rio de Janeiro show markers for systems thinking, appealing to relational information and taking multiple perspectives spontaneously.

Keywords
Culture, cognition, complex systems thinking

Introduction

Favelas are low-income communities that exist in close proximity to middle- and upper-class neighborhoods (*asfaltos*) in major Brazilian cities such as Rio de Janeiro. Despite governmental efforts to physically integrate *favelas* in the past 10 years, *favela* residents still have to deal with a deeply rooted stigma stemming from the dominant classes (Silva, 2005). Compounding this problem is the largely negligent and inefficient Brazilian public education system. Economists Bourguignon, Ferreira and Menéndez (2007) found that the public education system in Brazil systematically discourages intergenerational educational mobility and produces chronic underachievement among low-income communities. In addition, an overwhelming number of middle-class families send their children to

DOI: 10.1163/15685373-12342089

private schools, creating a sizable gap between the educational achievement of middle-income and low-income children (José Francisco, 2006).

Despite this education gap, my exploratory work suggests that the *favela* environment creates a unique set of circumstances leading to the existence of nontraditional ways of thinking and learning. In particular, life in *favelas* may encourage thinking and learning that requires taking multiple perspectives and focusing on relationships. Such habits of mind are valued when engaging with complex systems—systems composed of interconnected agents whose interactions as a group may create emergent phenomena that, in a sense, are more than the "sum of their parts." For example, a corporation is not just an aggregation of people, but a system of interconnected agents who create products, market trends, and impact consumers.

A propensity to adopt habits of mind that facilitate systems-level thinking could have intriguing educational implications for the *favela* population in that it might be leveraged to create educational achievement (Moll et al., 1992) for subject matter where complex systems are central to understanding the core phenomena (e.g., science; National Research Council, 1996). In summary, the present study is a preliminary exploration of the cognitive differences of people socialized in *favela* and *asfalto* environments in Rio de Janeiro. Before describing the study in detail, I will first place it in a broader theoretical context.

Deciding what markers constitute systems thinking is based on two theoretical perspectives. The first is thinking in levels from the field of the Learning Sciences, which studies learning and thinking about complex phenomena. The second is construal level theory from the field of Psychology, which relates one's psychological distance to how people think about a particular object. Combining these two theories allows us to identify empirically validated markers of complex systems thinking.

The field of complex systems endeavors to determine how emergent and adaptive behavior arises from interactions among simple entities (Mitchell, 2009). For example, ants, despite their small size, being almost blind, and being absent of a leader, are able to create a mass of movement capable of taking down and killing prey many times their size.

According to Resnick and Wilensky (1998), learning about complex phenomena requires thinking in levels. Due to the nature of our interconnected and ever-changing world, thinking in levels has become important to understand phenomena around us (Resnick and Wilensky, 1998). Theorists in this area have argued that thinking in levels has less to do with hierarchical levels than with taking multiple perspectives (Resnick and Wilensky, 1998; Wilensky and Resnick, 1999; Wilensky and Reisman, 2006). For example, when thinking about complex phenomena, we must simultaneously consider the micro level

by taking the perspective of the individual agent, consider the macro level by taking a step back and appreciating a third-person perspective, and connect the levels by attending to the relationships among individual agents (Resnick and Wilensky, 1998).

Resnick and Wilensky (1998) have further suggested that one needs to "gain an appreciation for the perspective of the individual while also gaining insights into how interactions among individuals give rise to larger patterns of behavior" (p. 167). For example, Wilensky and Reisman (2006) recounted the story of Paul, who investigated the behavior of fireflies to build a computer model showing how fireflies come to flash in unison. To uncover and understand the rules that the fireflies were following, Paul had to initially think like a firefly, taking its perspective.

The other theory relevant to systems thinking is construal level theory (CLT). This theory draws on two main concepts, the first of which is psychological distance, or the perception of how close or removed one is from an event in terms of distance, time, space, and socially (Trope and Liberman, 2010). The second concept of CLT is construal level, which is a person's perception of an object due to the psychological distance he or she has from that particular object (Trope and Liberman, 2010). The key idea of CLT is that psychological closeness is associated with a low level of construal in which people focus on the context and "hows" of actions, while psychological distance is associated with a high level of construal in which people focus on more abstract features and the "whys" of actions. A low level of construal is also claimed to lead to an increased likelihood of taking another actor's perspective.

Along these same lines, Wilensky (1991) proposed that the concreteness of an object is related to our relationship to it. If someone has a close relationship with an object, it becomes concrete. In contrast, if someone has a more distanced relationship with an object, it will be conceptualized as abstract. Similarly in CLT, with closeness, one pays attention to context, takes a first-person perspective, assumes spatial closeness, and thinks like the agent. However, if the relationship is more distanced, one pays less attention to context, takes a third-person perspective, assumes spatial distance, and the object becomes abstract.

Integrating across these two literatures, the following markers of thinking in levels will be employed: (1) the ability to see multiple perspectives, either by adopting different construals or more than one visual perspective of an object (Resnick and Wilensky, 1998; Wilensky and Reisman, 2006) and (2) a focus on relationships (Resnick and Wilensky, 1998). The central hypothesis of this study is that the socialization of *favela* residents causes them to develop an ability and propensity for making relational attributions and taking multiple

perspectives by shifting construal levels. In the framework of CLT, the hypothesis is that *favela* dwellers interact with their social environment from a psychologically close perspective, whereas *asfalto* dwellers interact with their social environment from a more distant perspective, making them less likely to adopt multiple perspectives with respect to their social environment.

Method

Research Participants and Site

There were 89 participants in this study (67 adults and 22 children); the mean age of the entire sample including the children was 33.5 years (SD=19.2). Forty-two participants had a middle-class background (37 adults and 5 children); the overall mean age was 36.3 years (SD=18.4). The mean years of schooling among middle-class participants was 14.3 years (SD=4.9), which is equivalent to a bachelor's degree in Brazil. Forty-seven participants had a *favela* background (30 adults and 17 children); the overall mean age was 31 years (SD=19.8). The *favela* sample came from eight different *favelas* around the state of Rio de Janeiro. The mean years of schooling among *favela* adults was around 7.3 years (SD=5.4), which is roughly equivalent to the seventh grade in Brazil.

Data Sources and Procedures

The interview consisted of a drawing task and 12 open-ended questions regarding Brazilian society that aimed at tapping into the differences in participants' reasoning. The present focus is on a subset of those questions, including two about the drawings that participants made of the places they lived and one about daily lives in their neighborhoods. The first interviewees contacted were students, parents, and employees from a community center in the *favela* of Chumbada in an outlying district of the city of Rio de Janeiro. People who agreed to participate were interviewed at a later date in their homes. A modified snowball sampling procedure was used where informants were asked to recommend another person for the interview who was as different from him or her as possible.

Results

Initially, participants were prompted to draw the places where they lived with the following question: *Você poderia desenhar o lugar onde você mora?* (Could you please draw the place where you live?) Once participants had finished

drawing, a follow-up question was asked to prompt them to describe their drawings: *Me conta o que você desenhou?* (Tell me about what you drew?) Later, participants were asked to talk about the daily lives in their neighborhoods with the following question: *Como é o dia dia em seu bairro?* (How is daily life in your neighborhood?)

The drawing instructions were deliberately ambiguous in order to make the task somewhat open-ended. Informants employed a range of ways of illustrating where they lived, and this variation was reliably correlated with their background. The drawings were coded for: (1) the adoption of a standard-level perspective or a bird's-eye perspective (Trope and Liberman, 2010); (2) the use of multiple perspectives (Wilensky and Reisman, 2006); (3) the number of relationships within the drawings; and (4) the level of detail and attention to context shown (a high level of detail should indicate a lower level construal; Trope and Liberman, 2010).

An interrater reliability analysis using the Kappa statistic was performed to determine consistency among raters by having a blind coder fluent in Brazilian Portuguese code 20% of the drawings. The first code, use of bird's-eye view, yielded a Kappa of 0.658 (p=0.005), which showed a substantial agreement among coders (Landis and Koch, 1977). The second code, the use of multiple perspectives, yielded a Kappa of 0.54 (p<0.000), which showed a moderate interrater reliability (Landis and Koch, 1977). The third code, which analyzes the use of relationships when describing the drawing, yielded a Kappa of 0.73 (p<0.001), showing substantial reliability among raters (Landis and Koch, 1977). The fourth code analyzes the number of focal objects in the participants' descriptions and yielded a Kappa of 0.748 (p<0.000), which indicates substantial agreement between the coders (Landis and Koch, 1977). The last code was based on participants' answers to the daily life question; a blind coder fluent in Brazilian Portuguese coded the data, yielding a Kappa of 0.667 for the code of self (p<0.003) and a Kappa of 0.778 (p<0.001) for the code of community, revealing a substantial agreement between raters (Landis and Koch, 1977). Two participants from the *favela* sample chose not to do the drawing task and the analyses are based on 87 drawings for both children and adult participants.

Bird's-Eye View

An aerial perspective was coded as a bird's-eye view (see Fig. 1). *Favela* residents were reliably more likely than middle-class residents to adopt an aerial stance, $\chi^2(1, N=87)=9.43^a$, p=0.002, phi=0.33. Middle-class mean use of bird's-eye view was 0.14 (SD=0.35), while *favela* participants had a mean of 0.44 (SD=0.50). The local geographic topography (e.g., living on a hill) might affect

Figure 1. Street-level view drawing versus a bird's-eye view drawing. This figure is published in colour in the online edition of this journal, which can be accessed via http://booksandjournals.brillonline.com/content/15685373.

use of a bird's-eye view. To address this question, the type of dwelling (high-rise or house) and the elevation of its location (hill or plain) were analyzed and there was no reliable correlation between those variables and the adoption of a bird's-eye perspective.

Use of Multiple Perspectives

Rather than depicting solely a street perspective or an aerial perspective, some participants drew mixed perspectives; for example, illustrating the inside and outside of a house, or using both an aerial view and standard view in one drawing (see Fig. 2). *Favela* participants were reliably more likely to appeal to multiple perspectives in a drawing. The results are statistically significant, $\chi^2(1, N=87)=15.237^a$, $p=0.000$, phi=0.418. While *favela* dwellers used multiple perspectives often ($M=0.40$, SD=0.50), the middle-class participants used it much less on average ($M=0.048$, SD=0.22).

Use of Relationships in the Drawing Description

The number of relationships mentioned by each participant when describing his or her drawing was also coded. Coded categories for relationships consisted of: (1) Prepositional phrases relating components of the drawings to each other (e.g., "This house is behind X street") and (2) relating components of the drawing to a personal episode (e.g., "This house is where my aunt lived; she liked to invite the whole family over every year"). As an illustration of what participants said, here is what Victor, a 40-year-old *favela* resident, told me about his drawing, followed by what Wilson, a middle-class resident, said about his.

Figure 2. A *favela* child's drawing that contains two perspectives. This figure is published in colour in the online edition of this journal, which can be accessed via http://booksandjournals.brillonline.com/content/15685373.

Victor:

> I'm going to draw the main street. Here we have the entrance, this would be a little bridge under the canal, which is called *canal*. To this side is a street called *Canal*, it ends this way. What we have here are alleys. These are stairs, more stairs here. Up here it's the *favela* per se, with the alleys and dead-end streets. There's a house here and a church where I started going, a Presbyterian church. Here there are stairs, the end leads to my house, where I live – where I used to live with my mom in this case. There are some curves, right? Here there are other stairs that lead where I used to live with my now-deceased aunt and this way there is a condominium called *Vila da Saudade*, that's the farm, that's where the more cultured people live. The houses – it's not an actual village and after some time it also became a community due to a large amount of criminals that thrived in that area. Nowadays, with the UPP ("Pacifying Police Unit"), it's going back to the way it used to be. So, that's more or less the drawing.

Wilson:

> I drew the hill because we live in a place called *Alto Botafogo*, which divides *Laranjeiras* and *Botafogo* and the things that are characteristic, there's a house that's really big, there are several floors, there's a lot of trees around the wall.

Victor and Wilson have drastically different explanations of their drawings. One is based on relationships and the other, while mentioning a few relationships, is mainly based on naming what is in the picture. Victor talked about who lived in the houses, where each street went, and he added stories about

the community. Wilson talked about what was in the pictorial representation but did not recall relationships or experiences that were not an immediate part of the drawing.

Overall, the *favela* participants referred to more relationships among the components of their drawings than the middle-class dwellers (*favela* M=3.2, SD=2.8; middle class M=1.05, SD=1.3). The *favela* sample talked about relationships an average of three times more often than the middle-class sample did, ($t(66)=4.58$, $p<0.000$) degrees of freedom adjusted for unequal variance; the magnitude of the differences in the means was large (eta squared=0.198). Since some participants seemed to use more words to express themselves, the number of relationships used in each answer were divided by the number of words each participant spoke, creating a ratio. Controlling for the number of words people used, the difference was still statistically significant. This suggests that *favela* residents appeal to a relational mindset more often in representing the places where they live.

Number of Focal Objects

The descriptions provided were also used to code the number of focal objects mentioned by participants. Figure 3 provides examples of drawings where the participant mentioned more than one focal object (left), and where the participant mentioned only one focal object (right). *Favela* residents mentioned reliably more focal objects than middle-class participants ($t(70)=2.56$, $p<0.013$) degrees of freedom adjusted for unequal variance. While *favela* residents mentioned an average of 4.6 focal objects (SD=3.4), middle-class residents mentioned an average of 3.1 (SD=1.9).

Neighborhood Daily Life Descriptions

The question posed to participants about their daily lives was open-ended and was variously interpreted as being directed at the individuals themselves and their daily routines, or as being directed at their community. Participants were asked: Como é o dia a dia em seu baino? (How is daily life in your neighborhood?). Participants who viewed themselves and their daily routine as the point of reference enumerated the activities they usually performed throughout the day, taking a first-person perspective. Participants who viewed their community as the point of reference described the daily lives of their communities, often taking a third-person perspective. Illustrating the contrast between an individually focused response and a community-oriented response are the following descriptions of daily life from a *favela* resident and a middle-class resident. First, the middle-class resident, Alessandra, followed by Marcus, a *favela* dweller.

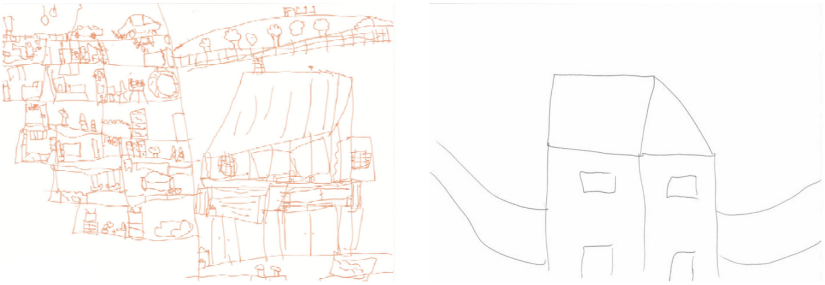

Figure 3. A drawing with more than one focal object and a drawing with one focal object. This figure is published in colour in the online edition of this journal, which can be accessed via http://booksandjournals.brillonline.com/content/15685373.

Alessandra:

> The day-to-day here [in] Botafogo? Well my life is very practical, I love my life here, I work one kilometer from my house, my daughter who is still young, goes back and forth with me. I have a maid who does, let's say the dirty service, you know, the one that nobody wants to do right . . . She does not sleep here every day, I have a very good relationship with her, I treat her as I like to be treated by my bosses, I have . . . we have this opening, we negotiate holidays and such, but well, I do not meddle with her service, as long as the house is clean and the food ready, I do not care . . . Then I'll come back from work, we also walk a lot here in Botafogo, no need to get stressed out with traffic . . . I think I have a good quality of life, there's a supermarket near here, the places we enjoy . . . I have a routine with the children to go to the bakery, eat a snack at the Boomerang cafe, an açaí, and [my son's] gym is also nearby, his school is nearby. I think that we have a very comfortable life, without stress you know? It's all very functional, just the ordinary.

Marcus:

> People mind their own businesses and show things off. For instance, someone plays music really loud here, some *pagode* would follow suit, then someone else would play some evangelical music, and someone else would play funk, rap. Then you'd have that mix of really loud music. Sometimes, you see a woman in a bikini on the roof, a guy passes by drinking beer. People were calm, right? And then suddenly, in a moment like this when you least expect it, the police comes in, everyone goes into hiding and everything is quiet – that apprehension, waiting to see what's going to happen. The police comes up, we don't hear about it in advance, whether they come to arrest anyone, whether to investigate anything, whether to get some money. We don't know what happens, we only know that after a crossfire the police would come up, they would suddenly leave and everything would go

> back to normal again, everyone with their own celebrations. That's when you'd see people come together, all that shouting. Like, someone, "Ah, I need some coffee, some sugar and such – so-and-so, do you have some coffee I could borrow?" "So-and-so is calling you." "There's a letter here from someone." That's what the daily life is like there more or less. You'd wake up early, go to work, everyone would go down together for work, take the same bus, get back late, take the same bus. That's roughly it.

While Alessandra referred to a few relationships in her discussion of daily life in Botafogo, especially her relationships with her maid and children, Marcus thought about simultaneous actions and relationships happening among a larger number of actors. When talking about the daily life in his neighborhood, Marcus took a third-person perspective and looked at the particular actions of different agents, rather than taking a first-person perspective, as Alessandra did. Marcus illustrated the relationships among agents in his description of residents' clashes in music, the interactions of people passing by, and police activity in the *favela*, while Alessandra's description of daily life translated into an orderly list of sequential events. Participants' answers were coded for either community or self. Some subjects gave answers that appealed to both stances, however, *favela* residents were more likely to answer about their communities. The results were statistically significant, χ^2 (1, N=87)=3.825[a], p=0.05, phi =0.20.

Discussion

The use of several focal objects, high level of detail, and attention to context suggest that *favela* residents adopt a low-level construal when creating a visual representation of their dwelling (Trope and Liberman, 2010). On the other hand, *favela* residents were more likely to draw a bird's-eye view of their communities, which is an indicator of a higher construal of society as suggested by the adoption of spatial distance (Trope and Liberman, 2010). These seemingly contradictory cognitive perspectives reveal *favela* dwellers' ability to shift construals within the same visual representation. This ability allows *favela* residents to take different perspectives when talking about daily life, as was evident in their attention to details when describing simultaneous isolated actions and relationships between actors, and when taking a step back and adopting a third-person perspective to answer questions. *Favela* dwellers were also more likely to adopt multiple spatial perspectives when drawing their houses. According to Libby et al. (2009), visual perspective is linked to perspective-taking, so the ability to take multiple perspectives when drawing translates into an important marker of thinking in levels.

Resnick and Wilensky (1998) suggest that to understand a complex system we must attend to the relational information within it. *Favela*-dwelling participants talked more about relationships when describing what they drew than did the middle-class participants. And analysis of the second question revealed that *favela* residents were more likely to think in terms of the collective and of the relationships within the whole. *Favela* residents viewed their daily lives through a multilayered and relational perspective, while middle-class residents were more likely to view their daily lives through a perspective centered on the self. This suggests that *favela* residents adopt a larger, more complex cognitive unit made up of more actors and relationships when drawing and talking about their immediate social environment. Their natural focus on relational information could be an important ally in complex systems thinking as it highlights relationships and creates a focus on multiple agents and processes among them.

This study suggests that *favela* residents have a propensity for shifting construal levels through psychological closeness with their social environments, making them more likely to focus on relational attributions and take multiple perspectives, while *asfalto* residents are less likely to adopt multiple perspectives and rely on relational information due to a more distant perspective with their social environments.

Conclusion, Implications, and Future Work

Brazilian society has a predisposition to undervalue low-income and working-class communities (Silva, 2005). Studies like this one begin to identify untapped potential within these environments. Despite the heterogeneity among the *favela* populations studied, there was a consistent pattern of results, revealing what Wilensky and colleagues have long advocated as a base for thinking in levels: the use of multiple perspectives and a focus on relationships. These markers signal the ability to build on the understanding of aggregate complex phenomena. *Favela* dwellers from diverse backgrounds exhibit these abilities with regard to their social environments, which they are psychologically close to. While this study was focused on the *favelas* of Brazil, these findings could potentially translate to other low-income communities around the world, creating visibility for alternative perspectives adopted in differing sociocultural and economic environments.

The evidence found in this study has far-reaching educational implications. For example, science education often starts with analytical pieces of information that are then built into systems of knowledge (Bang et al., 2007). This traditional approach would be incongruent with *favela* students' cognitive

orientations and should be adapted to accommodate their relational and multiple ways of seeing the world. Instead, students' experiences outside of school should be valued and explored, as they could potentially provide anchors for other formal educational experiences. According to Holland (1995), the most fruitful strategy for understanding complex systems is "to make cross-disciplinary comparisons in hopes of extracting common characteristics." Educators in Brazil could use *favela* dwellers' natural inclination for taking multiple perspectives and their focus on relationships within their immediate social environment to further explore other complex systems.

It is also important to highlight that this study does not imply the middle class cannot or does not show potential for thinking about complex systems. Rather, this study begins to show that psychological distance is one of the components to determine whether people will use the cognitive resources of adopting multiple perspectives and appealing to relational information, which result in thinking in levels. Because the *favela* dwellers are more psychologically close to their social environment, they were able to present more of those markers in their responses. Had the participants been asked about issues which the middle class is psychologically close to, the middle-class participants would probably have adopted a different perspective and presented the markers of complex systems thinking in their responses.

In the future, it would be interesting to examine whether these markers for systems-level thinking translate into a better understanding of and reasoning about complex systems. In that vein, later studies will examine participants' responses to a challenge question to find out the types of resources they appeal to when speaking about emergent phenomena in their society. Furthermore, it would be intriguing to study the kinds of perspectives and markers of complex systems thinking that people use to talk about inequality in Brazil. The goal of future work also includes ascertaining the implications of *favela* dwellers' psychological closeness for policy-making. Politicians, who reside outside of *favelas* and are likely psychologically distant from most of the problems that *favela* dwellers face, may not be able to make use of the relational information and perspective-taking necessary to satisfactorily solve certain complex issues that *favela* dwellers experience. If *favela* dwellers are able to take a psychologically close perspective of societal problems within their social environments, the most appropriate solution for those problems could best come from within this particular population.

Acknowledgement

I am indebted to Dr. Doug Medin, Dr. Mike Horn and Dr. Rumen Iliev for all their support with this research.

References

Bang, M., Medin, D. L. and Atran, S. (2007). Inaugural article: Cultural mosaics and mental models of nature. *Proceedings of the National Academy of Sciences of the United States of America* 104, 13868-13874.

Bourguignon, F., Ferreira, F. H. G. and Menéndez, M. (2007). Inequality of opportunity in Brazil. *Review of Income and Wealth* 53, 585-618.

Holland, J. (1995). *Hidden order: How adaptation builds complexity*. Addison-Wesley, Reading, MA.

José Francisco, S. (2006). Measuring cognitive achievement gaps and inequalities: The case of Brazil. *International Journal of Educational Research* 45, 176-187.

Landis, J. R. and Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics* 33, 159-174.

Libby, L. K., Shaeffer, E. M. and Eibach, R. P. (2009). Seeing meaning in action: A bidirectional link between visual perspective and action identification level. *Journal of Experimental Psychology: General* 138, 503-516.

Mitchell, M. (2009). *Complexity: A guided tour*. Oxford University Press, Oxford.

Moll, L. C., Amanti, C., Neff, D. and Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory Into Practice* 31, 132-141.

National Research Council. (1996). *National Science Education Standards: Observe, interact, change, learn*, 4th edn. National Academy Press, Washington, DC.

Resnick, M. and Wilensky, U. (1998). Diving into complexity: Developing probabilistic decentralized thinking through role-playing activities. *The Journal of the Learning Sciences* 7, 153-172.

Silva, J. (2005). *Favela: Alegria e dor na cidade*, 1st edn. Senac Rio, Rio de Janeiro.

Trope, Y. and Liberman, N. (2010). Construal-level theory of psychological distance. *Psychological Review* 117, 440-463.

Wilensky, U. (1991). Abstract meditations on the concrete and concrete implications for mathematics education. In Harel, I. and Papert, S. (Eds.), *Constructionism: Research reports and essays, 1985-1990*, pp. 193-203. Ablex, Norwood, NJ.

Wilensky, U. and Reisman, K. (2006). Thinking like a wolf, a sheep, or a firefly: Learning biology through constructing and testing computational theories – an embodied modeling approach. *Cognition and Instruction* 24, 171-209.

Wilensky, U. and Resnick, M. (1999). Thinking in levels: A dynamic systems approach to making sense of the world. *Journal of Science Education and Technology* 8, 3-19.