Reframing the Role of Boolean Classes in Qualitative Research From an Embodied Cognition Perspective

Mitchell J. Nathan, University of Wisconsin-Madison, 1025 W. Johnson St, Madison, WI 53706-1796
Kristi Jackson, University of Colorado-Boulder and QuERI, 801 Pennsylvania, #205, Denver, CO 80203

Abstract: The prominent role of Boolean classes in qualitative data analysis software is viewed by some as an encroachment of Logical Positivism on qualitative research methodology. Rather than expressing some transcendent notion of a universal logic of formal entities (e.g., sets) that supercedes our knowable experience, we articulate an embodiment perspective, whereby Boolean classes are conceptual metaphors for apprehending and manipulating data, concepts and categories the same way we perceive and manipulate worldly objects and containers. Drawing on examples from seminal approaches to qualitative methods, we demonstrate how one central aspect of qualitative research practices—the process of coding data—can productively be viewed in terms of collecting and containing concepts and categories in this embodied sense. We discuss the implications of this for coding and for bridging qualitative and quantitative methods of inquiry.

Boolean Classes & Qualitative Research

Boolean classes (BCs) are part of a system of combination developed by the self-taught mathematician George Boole (b. 1815-1864) that uses algebraic notation to describe the relationships between groups (classes) and their members using the operations AND, OR, NOT, and Exclusive-OR (XOR; e.g., You can win what is behind *either* Curtain Number One or Curtain Number Two, but not both). The prominent role of Boolean classes (BCs) and operators within qualitative data analysis software packages is seen by some social scientists as employing strategies that "go against the purpose and value of qualitative research" (Roberts and Wilson, 2002, para 44), partly because these software packages are "based on a positivistic orientation to the social and natural worlds" (para 22). The emphasis on coding and retrieval (Coffee, Holbrook and Atkinson, 1996) in qualitative data analysis fosters a more homogeneous approach to qualitative data than exists in the qualitative research world, and therefore undermines qualitative methodology as a viable, non-positivistic alternative toward inquiry. Such claims rely on a connection between positivism, mathematics, and Boolean Logic, and find Boolean Logic to be a somewhat pedantic and uniform approach. In doing so, critics assume that Boolean Logic is an outgrowth of mathematics, and that the standardization and classification of mathematics drives a logic that is far too simplistic and positivistic to foster a rich analysis of qualitative data.

We contend that it is a common misconception that BCs are *derived from* mathematics and capable only of implementing a positivist approach to data analysis. Drawing on work by Lakoff and Johnson (1980, 1999) and Lakoff and Nunez (2000; Nunez, 2000), we argue that BCs are more precisely regarded as *conceptual metaphors* of some of the embodied ways that humans naturally perceive and act upon everyday things in the world, such as objects, categories, and containers. By "embodied ways," we mean that they are rooted in our actions and perceptions, even when we are considering abstract entities. They are metaphoric relations in that they stipulate a unidirectional, cross-domain mapping that preserves the inferential structure of the source domain (objects) when it is applied to the target domain (concepts). Rather than expressing some transcendent notion of a universal logic of formal entities (e.g., sets) that supercedes our knowable experience, BCs can be conceptualized as metaphors for apprehending and manipulating concepts and categories the same way we perceive and manipulate objects and containers. As Nunez (2000) notes, "conceptual metaphors are not mere figures of speech," nor "pedagogical tools," but hypothesized "cognitive mechanisms" that support abstract inference in the new domain of inquiry (p. 10). In this view, the meaning and behavior of BCs are actually grounded in and constrained by bodily and neural-perceptual processes. These include processes for how we perceive object boundaries (e.g., Hubel & Wiesel, 1968) and groups (e.g., subitizing), and how we tend to perceive and organize collections. The Gestalt laws of *Pragnanz* (Figure 1; similarity, proximity, continuity, symmetry, and closure; Arnheim, 1974) illustrate these principles and constraints. In this article, we explore the current debate on the role and impact of BCs in qualitative data analysis software (QDAS) packages, discuss the nature of BCs from the perspective of embodiment theory, and explore implications of the embodiment view of BC on the qualitative/quantitative paradigm wars in an attempt to promote more effective ways of sorting through the real differences and similarities.

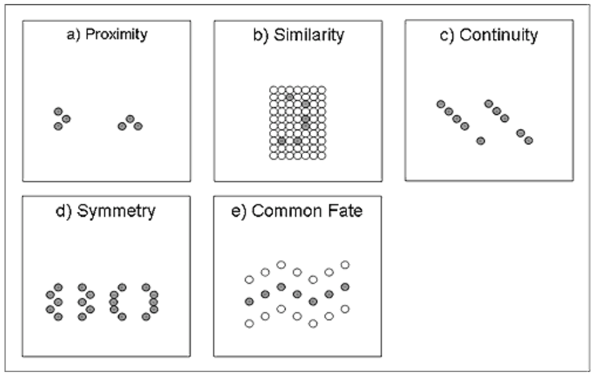

Figure 1. Gestalt principles of perceptual organization that mediate how we form collections: The Laws of Proximity, Similarity, Continuity, Symmetry and Common Fate.

The Debate Over Boolean Classes In Qualitative Research

In 1996, Coffey, Holbrook, and Atkinson produced an article that critiqued the use of QDAS as a tool that fostered a uniform approach to qualitative data and ignored a diversity of representational devices. Lonkila (1995) also stated that the act of coding qualitative data was overemphasized in QDAS, given the thoughtful, interpretive work that is necessarily part of qualitative analysis. Lee and Fielding (1996) challenge this view with their own studies showing that software users took many different approaches to the coded data *after* retrieval. Far from being the orthodox, monolithic shaper of analysis, computer programs made some procedures possible that were impractical to conduct prior to their emergence. Lee and Fielding concluded coding and data-reduction may be a *necessary* precursor to other interpretive strategies.

Since these original arguments were made, the capabilities of software packages such as NVivo, MaxQDA, Atlas.ti and Transana have expanded. Nonetheless, there seems to be little discussion about the implications of the Boolean debate on coding practices or on bridging quantitative and qualitative research methods. Despite this, QDAS bias and searches based in Boolean Logic clearly remain issues beneath much of the discourse on the use of software to analyze qualitative data. In his *Dictionary of Qualitative Inquiry*, Schwandt (2001) notes that every tool has an ideological bias, and so, too, must QDAS. He also states that while this awareness may be more often expressed by developers and frequent users of QDAS, he does not provide examples of the bias, or where to turn for such a discussion. Frankly, this is because little substantive discussion exists regarding QDAS bias in the published literature.

One of the most recent publications describes the various phrases currently used in QDAS programs to conduct searches that are based in Boolean Logic (Query Tools, Search Procedures, Hypothesis Testers, Index Search Operators, and Logic Machines). Echoing part of the earlier debate, Creswell and Maietta (2002) provide a framework for comparing software tools according to eight types of features, which include concept combination tools as listed above (searches based in Boolean logic, and dependent on some form of coding), as well as conceptual maps, (which draw on tools that support creation of relations to support a network-level understanding). This categorization of tools parallels comparisons in earlier debates (Coffee at al, 1996; Barry, 1998) that placed some packages in the more sequential and linear (hierarchical coding) camp, and others in the more complex and inter-connected (conceptual mapping and hypertext links) camp. Nonetheless, the authors provide no discussion on the relationship of these tools to fundamental cognitive processes. Such a discussion would contribute to a deeper understanding of when to use the various tools – including Boolean searches – to further a rich analysis of qualitative data. . It is to this discussion that we now turn.

Embodiment View: Where Classes Come From

The embodiment view (e.g., Clark, 1999; Dreyfus, 1992; Heiddegger, 1962/1927; Merleau-Ponty, 1962)—as well as related fields such as Embodied Cognition (e.g., Glenberg, 1997, 2000; Lakoff & Johnson, 1980, 1999) and Ecological Psychology (Gibson, 1979)—frames the structure and development of human behavior and human thinking in terms of the central role of the environment and the sensori-motor processes that mediate environmental interactions. One key idea is the way interactions with physical entities become appropriated as a means to describe interactions with *conceptual* entities. In their book, *Where Mathematics Comes From*, Lakoff and Núñez (2000) argue that the formal notion of *class,* as articulated by Boole in the 1840's and 1850's, draws upon our everyday perceptions of and actions on collections of objects and containers. Containers bound regions of space that visually and tactilely determine what is and is not contained (see Figure 2). (Although many alternative psychological models of conceptualizing groups and categories have been developed--e.g., fuzzy sets, probabilistic membership, prototypes--the container metaphor has enjoyed great prominence, both historically, and for its simplicity as a first-order account of human cognition (e.g., Bruner, Goodnow & Austin, 1956).) Reasoning with and about containers is dependent upon a rich container schema, a general mental construct for thinking about how to hold and store things that humans develop through their many and varied interactions with the world (Lakoff & Johnson, 1980). It is from schemas such as that for containers that we generalize our sensory experiences such as *on, in*, *with*, and so forth, and apply them to new entities.

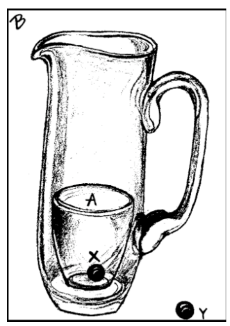

Figure 2. An illustration of how object-container relations parallel those found in Boolean Logic (adapted from Lakoff & Nunez, 2000).

Conceptual metaphor is the mechanism by which we apply such sensori-motor constructs like a container schema more broadly (Lakoff & Johnson, 1980). Metaphor (Bowdle & Gentner, 2005) allows "us to reason about one kind of thing as if it were another" (Lakoff and Núñez, 2000, p. 6). It is a powerful, general means by which we can extend our experience and understanding of the behavior and perceptions of familiar objects to include entities with very different properties. The use of metaphor in embodiment theory is not merely as a figure of speech, but a basic neural mechanism that allows us to use the inferential structure of one conceptual domain (say, the aggregation of similar objects) to reason about another (say, the aggregation of similar ideas). The composition of our container schema is determined by our evolutionary, neural, perceptual, historical, and cultural make up. That is, it is a product of our experiences and the norms of interaction of the people and artifacts that we interact with, while also highly influenced by the ways our bodies allow us to move within, manipulate, and perceive the world. These influences determine both what we recognize as containers and how we interact with them through actions and discourse.

Through conceptual metaphor, we readily apply our notion of a container to many other entities. Speakers will spontaneously use a gesture signaling a container when discussing something as abstract and ephemeral as a genre of film they are asked about (McNeill, 1992). For example, in one interview, a speaker responds "It was a Sylvester and Tweety cartoon," and makes a gesture indicating he is "opening" up an invisible container before him to discuss the specific events that unfolded as though they were its contents. In spoken language, we regularly use container metaphors to describe many non-physical entities, such as personal beliefs, intellectual development, and organizational structure (e.g., "Ann is *in* the Educational Psychology Department."). Concepts are, of course, not objects. They lack mass (though we talk about "weighty ideas"), matter (though they may have or lack "substance"), and form (though they can be "slippery" or "over-arching"). Yet, we naturally appropriate the perceptual, motoric, and cognitive processes that we have developed from our experiences with objects for our conceptual apparatus of classes and members. In the language of embodiment theory, our pre-existing notions of objects and containers serve as *grounding metaphors* for our new notions of concepts and theories. We talk about, think about, and even make inferences about conceptual entities in a manner that is in keeping with our thoughts about objects.

Consider the arrangement depicted in Figure 2 (Lakoff & Nunez, 2000). There is much we can say about the visual/physical arrangement of objects x and y and containers A and B: If object x is in container A it is also in B; if object y is outside of container B it is also outside of A; and so on. Indeed, the four basic Laws of Logical Inference, reproduced for convenience in Table 1, can be seen in Figure 2. Far from exhibiting a transcendent quality of universal truth, these laws emerge simply as abstractions from our everyday engagement with objects and containers. In this way, BCs are simply metaphorical extensions of everyday classes. The representational power of BCs, then, follows from the entailments that they share with the behavior, affordances, and constraints of collections of physical objects.

Table 1. The four basic laws of logical inference.

Excluded Middle: Every element X is either a member of class A or not a member of class A.
Modus Ponens: Given classes A and B and an element X, if A is a subclass of B and X is a member of A, then X is a member of B.
Hypothetical Syllogism: Given three classes A, B, and C, if A is a subclass of B and B is a subclass of C, then A is a subclass of C.
Modus Tollens: Given two classes, A and B, and an element Y, if A is a subclass of B and Y is not a member of B, then Y is not a member of A.

As evidence that the container metaphor extends beyond mere speech, inferences that may naturally follow physical containers and objects, such as those depicted in Table 1, can also be imputed to conceptual entities. Thus, following the earlier example of organizational structure, if the Educational Psychology Department is *in* the School of Education, one can conclude, therefore, that Ann must also be *in* the School of Education.

Inquiry Methods Must Make Meaning

One of the central issues in embodiment theory is the need for representations, such as propositions and diagrams, to be meaningful in order that they are accepted by agents who may be listening to or viewing them. Glenberg (1997) argues that our ability to discriminate between meaningful and nonsensical statements—to *understand* them—stems from our natural evaluation of the affordances of the entities in question. Affordances (Gibson, 1997) are the ways that we, as agents with particular body types and sizes (bipedal bodies that are upright, with opposable thumbs and stereoscopic vision) that vary with age, gender, experience naturally interact with the environment. When we evaluate statements such as After wading barefoot in the lake, Erik used his shirt [glasses] to dry his feet as meaningful or nonsensical, we are considering the affordances of the objects referred to in the sentences and considering (through a process of *envisionment*) the plausibility that they combine, or *mesh*, in a coherent manner.

Glenberg (1997) argues that our understanding of statements is mediated by our ability to index words and phrases to objects in the world, or analogical representations of objects such as pictures, inscriptions, or perceptual symbols (Barsalou, 1999). Glenberg's Indexical Hypothesis states that we derive affordances from the objects (or their analogical representations) that these words index, and assess meaning from the *combination of affordances*, rather than the combinations of the words themselves. Evidence from a number of studies examining readers' understanding of statements about orienteering (Glenberg & Robertson, 1997) and narratives about farms (Glenberg et al., 2004) support the hypothesis that the ability to index words to objects greatly facilitates comprehension. When readers cannot index the words to the physical entities, they may still exhibit simple recall, but they do poorly on tasks that require them to use the objects being referred to (Glenberg & Robertson, 1997).

Meaning making is an essential element to inquiry, and ultimately is one of the most significant criteria upon which we evaluate whether we are doing productive research in education and the Learning Sciences. The meaning of the actions and products of our inquiry must be continually assessed during inquiry in order to monitor its validity. It is likely to be insufficient to rely solely on the syntactic properties of operations to achieve meaningful results for all but the simplest areas of inquiry. That assessment of meaningfulness—as argued by Glenberg and Roberts, and by Lakoff, Johnson and Nunez—comes from our embodied experience. As Nunez (2000) reflected, "The truths of these traditional [Boolean] laws of logic are thus not dogmatic. They are true by virtue of what they mean."

Implications for Coding: Categories and Classes in Qualitative Research

By building on these ideas about Boolean Logic, we hypothesize that the process of coding data is inherently a way of collecting and containing data, and is commonly found in seminal studies and qualitative methods handbooks. To investigate this hypothesis, we sampled from some of the most frequently cited authors in the arena of qualitative coding to examine the ways in which they describe (and often instruct) the process of coding. To begin, we have Glaser and Strauss's (1967) constant comparative method, in which the unit of comparison changes from looking at incidents in relation to each other to looking at an incident and then comparing that with the properties that emerged from the initial comparison of incidents. In their book, Glaser and Strauss present the example of comparing the responses of nurses to a patient who dies. The category of "social loss" emerges as various comments are compared, such as, "he was to be a doctor" and "what will her husband and the children do without her?" As the authors note (p. 206), the "theoretical properties of a category" become generated fairly quickly with this comparison of incidents to each other and to the other evolving categories.

In Spradley's (1979) domain analysis, any symbolic category, such as "tree," can include other categories, such as "oak," "pine," and "aspen." Spradley claims that domains are the first and most important unit of analysis in ethnographic research, and that the discovery of these terms allows for an understanding of cultural knowledge from the perspective of various social actors. Every domain has a *boundary*, which allows us to ascertain inclusion or exclusion, "no, this isn't a tree, it's a bush." Finally, far from being a pedantic, simplistic approach, he notes that identifying and analyzing what he calls folk domains is one of the most difficult tasks faced by ethnographers. Spradley's proposal of universal semantic relationships (p. 111) is also intriguing for its parallels with Boolean Classes (Table 2). These semantic relationships all require the notion of container schemas as the basic building blocks for coming to understand the world view of a cultural actor in the context of larger, socially produced patterns.

Table 2. Spradley's (1979, p. 111) universal semantic relationships.

1. Strict inclusion: X is a kind of Y	6. Function: X is used for Y
2. Spatial: X is a place in Y, X is a part of Y	7. Means-end: X is a way to do Y
3. Cause-effect: X is a result of Y, X is a cause of Y	8. Sequence: X is a step (stage) in Y
4. Rationale: X is a reason for doing Y	9. Attribution: X is an attribute (characteristic) of Y
5. Location for action: X is a place for doing Y	

Finally, LeCompte and Schensul (1999) specifically discuss coding as a name or symbol that represents a group of similar terms, ideas or phenomena. LeCompte and Schensul see a connection between this kind of thoughtful, systematic coding and the kind of thinking people do in everyday life – except that theorizing is done in a more systematic manner through the processes of perceiving, comparing, contrasting, aggregating, ordering, establishing linkages/relationships, and speculating. None of these scholars who address the processes of handling data claim that coding is the culmination of the research process or that it should dominate the research process. Furthermore, they each present different ways of orchestrating the research process. However, they do imply that coding and comparing codes/categories is an essential part of qualitative methodology.

Implications For Bridging Qualitative and Quantitative Methods

Our interest in qualitative research, Boolean Logic, and QDAS stems, in part, from claims such as Lokila's (1995) that the positivistic orientation of software packages is somehow antithetical to qualitative research and more akin to quantitative research. Recent literature on mixed methods (Creswell, 2003) has helped break through the boundaries of qualitative and quantitative approaches to demonstrate that they may be combined in many different ways, and for many different reasons. While the debates in education research still include some stances on the ways in which qualitative and quantitative research differ, these arenas are more easily identified with extreme examples and are more difficult to separate when drawing near the fine line between them. Recent debates such as those regarding scientific research in education demonstrate that the perception of these boundaries is quite real, and loaded with political implications.

However, this debate also serves as one of the vehicles through which we are engaging in new discussions of research that explore (and expose!) the potentially tenuous boundaries between qualitative and quantitative research. Dohan and Sanchez-Jankowski (1998) noted that the terms quantitative and qualitative are often misunderstood, because they refer to differences in epistemologies, and not to the use of data per se. If we are to better understand these epistemologies, we must re-examine our categories of and within research. Some researchers become entrenched in the notion that, for instance, Boolean Logic is somehow more quantitative than it is qualitative.

For instance, one common understanding of qualitative data is that codes may be modified as the research progresses and as additional reflections by the investigator present new ways of understanding the data. In quantitative research, however, we often assume that codes, once chosen, must not be changed. Rather than simply ascribe to these rules, we would be more prudent, as Dohan and Sanchez-Jankowski (1998) imply, to focus less on the type of data, and more on the research questions and assumptions. By doing so we can then ask "why" or "why not?" regarding the static or dynamic status of a code, regardless of whether we are examining a qualitative or quantitative piece of data. A careful and productive look at our own socially defined categories of quantitative and qualitative research might be achieved by an extension of the process used here to understand how we use containers and metaphors to make sense of our world and to build conceptual frameworks.

References

Arnheim, R. (1974). *Art and Visual Perception: A psychology of the creative eye*. University of California Press.

Barry, C. A. (1998). Choosing qualitative data analysis software: Atlas/ti and Nudist compared. *Sociological Research Online, 3*(3). Retrieved Oct. 1, 2005, from http://www.socresonline.org.uk/socresonline/3/3/4.html

Barsalou, L. W. (1999). Perceptual symbol systems, *Behavioral and Brain Sciences, 22*,4:577-660.

Bowdle, B., & Gentner, D. (2005). The career of metaphor. *Psychological Review, 112*(1),. 193-216.

Bruner, J.S., Goodnow, J.J., & Austin, G.A. (1956). *A Study of Thinking. New York: Wiley.*

Clark, A. (1999). An embodied cognitive science? *Trends in Cognitive Science 3*:9, 345-351.

Coffey, A., Holbrook, B & Atkinson, P (1996). Qualitative data analysis: Technologies and representations. *Sociological Research Online*, *1*(1), Retrieved October 1, 2005 from http://www.socresonline.org.uk/socresonline/1/1/4.html

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks: Sage Publications.

Creswell, J. W, & Maietta, R. C. (2002). Qualitative research. In D. Miller & N.J. Salkind (Eds.), *Handbook of research design and social measurement*. Thousand Oaks: Sage Publications.

Dohan, D. & Sanchez-Jankowski, M. (1998). Using computers to analyze ethnographic field data: theoretical and practical considerations. *Annual Review of Sociology 24*, 477-498

Dreyfus, H. (1992). *What computers still can't do*. Cambridge: MIT Press.

Gibson, J.J. (1979). *The Ecological approach to visual perception*. Boston: Houghton Mifflin

Glaser B. and Strauss, A. (1967). *The discovery of grounded theory.* Hawthorne: Aldine de Gruyter.

Glenberg, A. (1997). What memory is for. *Behavioral and Brain Sciences, 20*(1), 1-55.

Glenberg, A. M., Gutierrez, T., Levin, J. R., Japuntich, S., & Kaschak, M. P. (2004). Activity and imagined activity can enhance young children's reading comprehension.. *Journal of Educational Psychology, 96*, 424-436.

Heidegger, M. (1962). *Being and Time*. New York: Harper & Row. [Originally appeared as Heidegger, M. (1927). *Sein und Zeit*. TÃbingen, Germany.]

Hubel, D. H. and Wiesel, T. N., (1968). Receptive fields and functional architecture of monkey striate cortex. *J. Physiol. 195*:215-243.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago, IL: University of Chicago Press.

Lakoff, G. & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to western thought*. New York: Basic Books.

Lakoff, G. & Nunez, R. E. (2000). *Where mathematics comes from*. New York: Basic Books.

LeCompte, M. & Schensul, J. J. (1999). *The ethnographer's toolkit: analyzing and interpreting ethnographic data*. Walnut Creek: Alta Mira Press.

Lonkila, M. (1995). Grounded theory as an emerging paradigm for computer-assisted qualitative data analysis in U. Kelle (Ed) *Computer-Aided Qualitative Data Analysis.* London: Sage.

McNeill, David (1992). *Hand and mind: What gestures reveal about thought.* Chicago: Chicago University Press.

Merleau-Ponty, M. (1962). *Phenomenology of perception*. London: Routledge (Originally appeared as Merleau-Ponty (1945) *Phenomenologie de la Perception*, Paris: Gallimard.

Nunez, R. E. (July, 2000). Mathematical ideas analysis: What embodied cognitive science can say about the human nature of mathematics, *Proceedings of PME 24*, Hiroshima, Japan, Vol.1, 3-22.

Roberts, Kathryn A. & Wilson, Richard W. (2002, May). ICT and the research process: Issues around the compatibility of technology with qualitative data analysis [52 paragraphs]. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research* [On-line Journal], *3*(2). Available at: http://www.qualitative-research.net/fqs-texte/2-02/2-02robertswilson-e.htm.

Schwandt, T. A. (2001). *Dictionary of qualitative inquiry*. Thousand Oaks: Sage Publications.

Spradley, J. A. (1979). *The ethnographic interview.* New York: Hold, Rinehart and Winston.

Varela, F. J., Thompson, E. & Rosch, E. (1991). *The embodied mind: Cognitive Science and Human Experience*. Cambridge: MIT Press.

Acknowledgements

This research was funded in part by a grant entitled "Understanding and Cultivating the Transition from Arithmetic to Algebraic Reasoning," awarded to the first author by the Interagency Educational Research Initiative, an alliance of the National Science Foundation, the Department of Education's Institute of Educational Sciences, and the National Institute of Child Health and Human Development within the National Institutes of Health. We also extend our thanks to Tom Richards, Lyn Richards, Chris Thorn, Katie Clnton, and Margaret Eisenhart who all provided us with valuable discussions and comments during the genesis of this work.