# Computer Simulation: What's the Story?

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*Computer simulation appears often in management theory development. However, computer simulation poses unique difficulties for many researchers and practitioners to understand. The author suggests the utilization of qualitative foundations will illuminate this type of quantitative research. Storytelling facilitates the use of that specific qualitative program (ethnostatistics). Storytelling elements explicate the patterns developed, found, and reported within the computer simulation methodology. An example of the framework developed is given.*

> "Far better an approximate answer to the correct question than an exact answer to the wrong question."
>
> John Tukey, 1962

## INTRODUCTION

The increase in computer processing speed and the proliferation of computers has contributed to the increase in problem solving. The classic traveling salesman problem (Robinson, 1949), which was first calculated to 49 cities (Dantzig, Fulkerson, & Johnson, 1954), has now been calculated to 25,000,000 cities (Applegate, Cook, & Rohe, 2003). Such a solution, possibly unfathomable when first posed, would not be possible without the benefit of computer processing speed and the ease of use for computers in general. Of course, the practicality of a traveling salesman tour of 25,000,000 cities contributes little to social science research, but does illustrate computing efficiency in problem solving.

The increase in computing problem solving generally means that researchers simply input data on one end and receive answers on the other. There is a special kind of ignorance of what may be happening in the middle, what may be happening in the computer. Researchers previously toiled long hours to calculate, recalculate, theorize, retheorize, and conceptualize their hypotheses and research question, now there is less time spent theorizing as data is entered in the front and results 'magically' appear at the end. This has led to a brand new term 'harking' or hypothesizing after results are known (Kerr, 1998), where researchers produce output, and then create their hypotheses to match the data. Therefore, the question becomes with this ease in calculation and manipulation has human reasoning and theorizing in social sciences been factored out?

Social science researchers recognize that most of human behavior is the result of interdependent, yet simultaneous processes that are increasingly complex (Harrison, Lin, Carroll, & Carley, 2007). The understanding of these multiple interdependent processes is contingent upon development of theory and research on the consequences of that theory. The main limitation of traditional approaches to theory development and research is the simultaneous evaluation of these interdependent processes. If the

individual processes are developed fully, the simultaneous and interdependent presents difficulties, especially if the processes interact in unforeseen ways. The increase in computing power, particularly in the form of simulation, can aid in this respect.

Simulation is an increasingly essential methodological approach in the social sciences. Research efforts in fields such as human resources (e.g. Blundell & Costa Dias, 2009; Schultz, Schoenherr, & Nembhard, 2010), leadership (e.g. Ballinger, Schoorman, & Lehman, 2009; Hunter, Bedell-Avers, & Mumford, 2009), strategy (e.g. Adner, 2002; Zott, 2003), and entrepreneurship (e.g. Noel & Latham, 2006; Lomi, Larsen, & Wezel, 2010) employ simulation to develop the theory around the research questions. Despite these and similar studies, simulation-based methodology efforts remain largely debatable (Davis, Eisenhardt, & Bingham, 2007).

On one side of the debate, researchers advocate simulation as a means of theory development. When empirical data limitations exist, simulation supplies insight into complex relationships between constructs (Zott, 2003). Simulation, also, provides an analytically precise method for the assumptions and theoretical logic from verbal theories (Kreps, 1990; Carroll & Harrison, 1998) and outcomes of the interactions between multiple organizational processes as they develop over time (Repenning, 2002). Advocates suggest simulation developing new theory and extending existing theory by useful means.

The other side of the debate suggests that simulation provides little advance to new theory development (Davis, et. al., 2007). In fact, some researchers argue that the outcomes of simulation research are so complex as to render any theorizing as ambiguous and inconclusive (Fichman, 1999). Others imply that simulations are just "toy models" of phenomena (Robertson & Caldart, 2008) that simply restate the obvious or remove so much realism that no theoretical value is obtained (Chattoe, 1998). After all, most simulation models are at least based in part on some unrealistic assumptions (Rivkin, 2000), and the measured outcomes of the simulation models are bit strings that represent choices, strategies, organizations, etc. (Bruderer & Singh, 1996; Lennox, Rockart, & Lewin, 2010; Miller & Lin, 2010; Rivkin, 2001). Critics of simulation point to the lack of control by letting the machines do the work.

In our opinion, the contentious points in this argument are not in the methodology but the perception of the methodology. Skeptics believe that if the human reasoning and theorizing has been factored out in favor of computing and technology then how can one be sure that computer-generated data follows the correct means of scientific reasoning? If researchers using simulation could better relate what is happening and why at several key steps in the process, then those not as familiar with simulation can be assured that the scientific method is in tack. The elements of storytelling provide the relation point of what is happening and why, and ethnostatistics provide the key steps in the process.

Almost all human memory is story based (Schank, 1999). Information, while indexed and stored in different methods, it is retrieved by means of stories (Woodside, 2010). By using the components of storytelling, difficult principles are made clearer. Storytelling traces its origins back to Aristotle (350 BC) and some made modifications to the components (Boje, 2002; Burke, 1945), but the benefits to understanding difficult situations is well acknowledged. Therefore, story with many components provides a means to increased learning (Schank, 1999).

Ethnostatistics is the empirical study of the creation, use, and interpretation of statistics and numbers by academics, researchers, and other professionals (Gephart, 1988, 2006). It is during these three distinct steps in any quantitative process that ethnostatistics confirms whether the statistics or numbers used are effectively representing the phenomena. Ethnostatistics is an application of enthnomethodology (Garfinkel, 1967) to the field of statistics. By using this practical application, we can extend enthnomethodology to computer simulation. Often, simulation is investigated only for the use step of the process, but we believe that by carrying the story through all levels of ethnostatistics a better judgment of validity can be made.

Therefore, the purpose of this paper is to explore how a particular sophisticated technological quantitative methodology can avoid nagging questioning of results by maintaining sound qualitative principles throughout the process. Computer simulation is a particularly sophisticated technological tool utilized by some in the social sciences that has increased scrutiny of results. By marrying two particularly important pieces of qualitative methodology, namely storytelling and ethnostatistics, we will enhance the

benefit of computer simulation. The paper proceeds in the following fashion. First, a short review of computer simulation is conducted. Next, reviews of both storytelling and ethnostatistics with linkages to each other follow. Last, a review of some computer simulation articles illustrates the benefits of this approach.

## SIMULATION

Simulation is defined as the use of computer software or programming to model real-world processes, events, or systems (Davis, et. al, 2007; Carley, 2001). This definition is consistent with other definitions that describe simulation as virtual experiments (Macy & Willer, 2006; Carley, 2001), or more simply as a simplified picture of a part of the world that contains some of the real world's attributes and is much simpler than reality (March & Lave, 1975). Other functions for simulation include a heuristic tool to develop, hypotheses, models, and theories (Davis, et al., 2007, Hartman, 1996), as an experimentation tool for experiment support or numerical support, or as a pedagogical tool for understanding the process. As such, simulation is different from the prior schools of science deductive and inductive (Harrison, et al., 2007).

Previous scientific efforts relied on two methodologies: theoretical analysis or deduction, and empirical analysis or induction. In the deductive methodology, assumptions are formulated and then the consequences of the assumptions provide conclusions. Typically, these assumptions are formulated as mathematical relationships and the consequences suggest conclusions through mathematical proofs or derivations. This methodology led to many successes where mathematical techniques are tractable to determine the consequences adequately. However, in most cases of the social sciences, the stochastic nature of the social processes or possibly even the complexity of these processes led researchers to choose assumptions based on the ability to derive consequences rather than the correspondence to reality. Even when well-designed with correct variables, the mathematical equations can only be solved in special and limited cases, which rendering the results suspect.

Inductive science requires observations of the variables or data and then analyzing that data to illuminate the relationships between the variables. In social sciences, the inductive form of science tests the predictions of theoretical analysis. The major problem for inductive science is the availability of measurable and observable data. Variables that are difficult to measure such as organizational problems (Simon, 1996) or power level of suppliers need sub variables or other markers that represent the actual variables but typically not the variables themselves. Difficult variables to observe such as organizational trust or secret agreements make predictions of the theoretical almost impossible. In addition, comparable measures cross samples or possibly across time compound the availability of viable data rendering some inductive science suspect.

Simulation is the third way of doing science (Axelrod, 1997; Waldorp, 1992), because simulation is different from both deductive and inductive science in its goals (Axelrod & Tesfatsion, 2006). Simulation can handle the computational aspect of many more mathematical relationships, thereby overcoming the difficulties of the deductive sciences. At the same time, data availability is less difficult since simulation can produce 'virtual data' for use in its calculations. Rather than the historical view of what happened, and how, simulation looks forward to the future and what if type scenarios (Dooley, 2002). Because of these features then simulation allows researchers to make more realistic assumptions rather than analytically or data availability convenient ones. Finally, simulation allows researchers to generate hypotheses that are whole system integrated and consistent (Carley, 1999), while also allowing the experimental conditions to take place in as controlled an environment as is possible (Axelrod & Tesfatsion, 2006).

Simulation researchers use three different schools of practice; each delivers a different means of scientific results (Dooley, 2002). The first of these schools is systems dynamics. Systems dynamics entails identifying key stagnant variables that define the behavior of a system, and define the relationship of those variables through coupled, differential equations (Sastry, 1997; Repenning, 2002). Systems dynamics is an extension of differential equations, and allows multiple differential equations to be

coupled to simulate the behavior of the system. System dynamics is limited to a single level of analysis and a single entity. Although limited in scope, system dynamics bridges some of the inductive and deductive methods to simulation.

The next school of simulation is discrete event simulation. This school involves the modeling of the entire system as a system of individual entities evolving over time due to triggering events such as the availability of resources. This school contains such families of simulation as cellular automata, developed from game theory (Lomi & Larsen, 1996), and learning models, developed from psychology and simulated evolutions (Levinthal, 1997; Rivkin, 2000; Rivkin & Siggelkow, 2003). Both of these families model more than one level, such as the individual or society, and the interactions of agents between those levels. Multiple levels are necessary for investigating emergent phenomena. Emergent data are properties of a system that exist at a higher level of aggregation than the original description of the particular system.

The third school of simulation is agent-based simulation. Agent based simulation requires agents that are autonomous, sensing, and acting agents and represent an individual, groups, or entire organizations (Carley, 1995). These agents attempt to maximize, or sometimes minimize, their utility functions by interacting with other agents and available resources. Programmed schemas that are interpretive and action-oriented in nature determine agent behavior. Families in this school of simulation are multi-agent models, agent-based computational economics, agent-based models, and multi-agent systems. All of these families largely grew from the artificial intelligence community, including such grand projects as the original atomic bomb testing (Harrison, et al., 2007). This school has multiple levels of modeling, highly complex agents, with a myriad of complex interactions.

## STORYTELLING

Storytelling, particularly in organizations, is the preferred method of evaluating the relationships involving internal and external stakeholders (Boje, 1991). Berry (2001) notes, "Stories are a fundamental way through which we understand the world…By understanding the stories of organizations, we can claim partial understanding of the reasons behind visible behavior" (pg. 59). Individuals in an organization engage in an incremental refinement of the old stories within new events, especially during turbulent times. The old stories hold a type of precedent for the interpretation of current situation. Even during stable times, portion of the stories of organizational experience are told and retold in a social manner that serve as precedent for individual interpretation. Story is therefore an important but often times misunderstood development within the organization.

Academic research differs on story versus narrative versus even antenarrative (Boje, 2001). Stories perhaps exist as flowing soup (e.g. Weick, 1995), after plot is added (e.g. Czarniawska, 1997), or as fragmented, non-linear, unplotted speculation (e.g. Boje, 2006). For purposes of this paper, Ricoeur's endorsement of Gallie's (1968:22) approach is adopted:

> A story describes a sequence of actions and experiences done or undergone by a certain number of people, whether real or imaginary. These people are presented either in situations that change or as reacting to such change. In turn, these changes reveal hidden aspects of the situation and the people involved, and engender a new predicament, which calls for thought, action, or both. (1984:150).

Storytelling is a method of understanding relationships more than simply performance output numbers. The stories told by the individuals reflect a deeper comprehension of the situation than mere numbers might be able to provide.

The exploration of story requires an understanding of what is involved in the story. Aristotle (350 BC) proposed a set of poetics to describe story. Aristotle's poetics included:

- Plot – The incidents of the story, How the events or tasks of the story move along
- Character – The actors of the story, Who is performing the events or tasks of the story

- Theme – The purpose of the story, Why the events or tasks of the story are being done
- Dialog – The voice of the story, How the story is told
- Rhythm – The pattern of the story, How the story is told
- Spectacle – The stage of the story, What the actors look like, what the surrounding environment looks like

Burke (1945) modified Aristotle's six poetics into his Pentad of five elements of dramatism. The Dramatism Pentad combined aspects of Aristotle to model a 'who, what, where, how, and why' of theater. Burke argued that the dramatism pentad exposed different relationships within humans' symbolic use of action and communication. Burke suggested that he should have added frame to his Pentad to create a Hexad (Burke, 1972). Frame, as Burke argued, are a competition between the dialectic interaction of frames of acceptance and frames of rejection. Burke suggests that frames are the boundaries around which the communication or theatre take place.

Boje (2002) attempted to expand and align Aristotle's Six Poetics with Burke's Pentad (Hexad) and created a Septet Grammar of the Leadership Situation. In his Septet, Boje included all Aristotle's six poetics, replacing the rhythm that Burke collapsed with dialog to create scene and included the frame element. Additionally, Boje provided for a multitude of stories at the same time (polyphony). This addition meant that each element could have a multiple amount of elements working as a whole or in part with other elements in the Septet. Therefore, the pluralized elements note this polyphony of stories. Table 1 contains a summary of this development.

**TABLE 1**
**STORYTELLING THROUGH THE YEARS**

| Author | Aristotle (350 BC) | Burke (1945) | Boje (2002) |
|---|---|---|---|
| Definition | Poetics of Grammar | Dramatism Pentad (Hextad) | Theatrics of Leadership (Septet) |
| What is being done; the events, construction, or processes of the story | Plot | Act | Plots |
| Who is acting; the actors who are involved in the events or processes | Character | Agent | Characters |
| Why it is being done; the rationale employed in resolving the events or processes | Theme | Purpose | Themes |
| How the actors are doing the plot; the repetitive cycles, chaotic disruptions | Rhythm | Agency | Rhythms |
| How the actors are doing the plot; the thoughts of the actors in words | Dialog | | Dialogs |
| Where it is being done; the stage, costumes, | Spectacle | Scene | Spectacles |
| Boundary conditions; the context in which the plot can be accomplished | | (Frame) | Frames |

Using elements of Boje's Septet grammar, this paper will now move to linking ABM to the three moments of ethnostatistics. Only four elements will be used for this paper, plot, character, theme, and frame. Plot will illuminate the 'what' is being done, character the 'who', theme the 'why', and frame the boundaries. These elements directly tie the stated purpose of ABM. The exclusion of the remaining three

elements does not imply non-existence or unimportance, but is beyond the scope of what is compared in this paper. For this reason, only the four elements are utilized.

## ETHNOSTATISTICS

During the latter half of the twentieth century, social scientists turned to statistics as the method of transitioning from a subjective speculation to a true science (Gould, 1981). In doing so, social scientists endorsed, albeit tacitly, the instruction of Lord Kelvin: "When you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind" (in McCloskey, 1985: 54). This tacit endorsement facilitated statistical and quantitative research methods an iron fisted hold on social science research (Van Maanen, 1979).

Gephart (1988) in a review of statistical practices, particularly in the social sciences, coined the term ethnostatistics.

> (P)ropose the term ethnostatistics to refer to the study of how statistics are actually constructed and used, particularly in scientific research. The prefix ethno suggests a concern for the actual behavior, and the informal subcultural, folk, or ethnic knowledge and activities of statistics producers and users. This informal knowledge complements and extends the formal, codified technical knowledge involved in statistics. Ethnostatistics is concerned with the mundane, everyday life practices, and the lay and professional knowledge necessary to implement and use statistics…Ethnostatistics as a domain of empirical inquiry complements statistics as a technical field of science. [Gephart, 1988: 10]

Gephart (1988) suggests that ethnostatistics has three levels or moments of analysis: constructing numbers, analyzing numbers, and interpretation of numbers.

The first moment of ethnostatistics utilizes qualitative methods to study the naturally occurring activities and meanings in producing a statistic. Producing a statistic involves assembling data in a logical format. This assembly involves selection of phenomena to measure, observe, and then code the results. The particular variables must be selected and the resulting activities associated with the variables must be observed in their proper setting where practical constraints and other concerns can influence the observations and the measurement of those variables. Effort to minimize confounding behaviors that influence outcome is of particular concern. Quantitative methods may not accurately describe the variables in such a 'natural' setting or within its particular context.

The second moment of ethnostatistics examines the adequacy of the technical and practical assumptions of the statistical analyses. Of particular interest in the second moment is the use of one technical or statistical assumption when others are available and implicit assumptions about cognitive or social features of the research process. In this moment, researchers seek to explain and to critique potential problems with particular assumptions and practices, and to propose alternative assumptions and practices. Also, second moment ethnostatistics seek to understand the perspective of the statistician to discover and assess the limits of the chosen technical and practical assumptions. The contextual difficulties found in the first moment are generally glossed over in this moment.

The third moment concerns the rhetorical or persuasive presentations of technical or statistical output. Rhetoric is the study of the use of language; in particular, it is the art of persuasion or the production of a particular argument persuading a unique audience. A package of antimethodology rhetoric indicates what is done, what seems to persuade, and why. Rhetoric concerns itself with explicitness, precision, and parsimony of argument. Rhetoric does not imply evasiveness or deception as in the phrase 'mere rhetoric'; all sciences are rhetorical (McCloskey, 1985).

The observations of the first moment of ethnostatistics expose the researcher to the sometimes crude, always unbiased meanings and the tacit assumptions of relationships and activities. The first moment provides a basis for the assumptions and features implemented during the second moment of

ethnostatistics. The third moment of ethnostatistics provides a means of investigating the information and assumptions utilized in the first two moments and the third moment studies them. In general, the program of ethnostatistics allows the researcher to monitor across research methodologies as well as explore science at three moments that are mutually relevant but analytically separable.

## THEORETICAL LINKAGES

Recall that agent-based modeling involves pattern seeking. It is process up evaluation rather than a control down simulation. Using the ethnostatistic program as a medium of analysis, the utility of ABM will be evaluated. The threads of connection will be the qualitative research method storytelling. Table 2 summarizes important data gathering points from moment 1, assumptions to be evaluated in moment 2, and explications for results in moment 3.

**TABLE 2**
**ETHNOSTATISTICAL MOMENTS COMPARED TO STORYTELLING ELEMENTS**

| | Ethnostatistic Moment 1 | Ethnostatistic Moment 2 | Ethnostatistic Moment 3 |
|---|---|---|---|
| Plots | What specific events, relationships, or processes are to be studied | Model the explicit events, relationships, or processes; are there implicit events, relationships, or processes that impinge on the explicit ones? | Importance of the patterns found in relation to the events, relationships, or processes |
| Characters | Characteristics of the actors; What makes them unique? | Model characters; are they 'modelable' | Generalizability of characters and the patterns they followed |
| Themes | Deep understanding of why this is necessary or being done | Decision points and the criticality of those points measured out and modeled | Patterns found in decision made by model |
| Frames | Context of events, relationships, or processes | To what degree can the boundary conditions be modeled | Generalizability of patterns across contexts |

The first moment of ethnostatistics studies the assemblage of data and the meaning in the production of a statistic. Quantitative methods are generally unable to describe variables in an accurate way and therefore the employment of qualitative methods allows for the capture of the data. In the first moment of ethnostatistics, four elements of Boje's Septet Grammar provide an excellent tool for developing insights into the studied events. Carefully attention to accurate portrayal of these four elements from the stories gathered will successfully enable an agent-based model. The frame is the most important. This puts the process or relationship in the correct context. Without a proper context, a researcher may skew the rest of the data. The frame is also the most difficult to assess. The researcher must be conscious of correctly ascertaining this context. On the other end of the spectrum are the agents. The agents may be the easiest element to discover, but understanding the meaning wrapped up in the agents might also prove elusive. For this reason, theme is another important concern for the researcher. Theme provides a deeper understanding into the why question of the process or relationship. The researcher must delve deep to understand this issue in order to be successful. The final element is plot. The plot element in this instance will tie the understanding together. The plot is the thread running through the story itself. If all four of the elements are sufficiently satisfied, then the first moment will also be sufficiently satisfied.

The second moment of ethnostatistics is a study of the practical and statistical assumptions. In this moment, the researcher has selected the method by which to study the process or relationship. That method is ABM. The suggestion here is to pay attention to the four elements of story to build the correct model. As mentioned before, ABM can only provide descriptions based on the inputs. Creation of an incorrect model only leads to incorrect descriptions. Staying true to the elements of story eliminates this potential problem. As mentioned in the first moment, after careful consideration of four elements of story the researcher can build an accurate model of the studied process or relationship. This is not a trivial matter. A thorough understanding of the four elements is essential before moving to the model-building phase. If the correct data is not discovered in the first moment then time spent in the second moment is wasted. This is the point at which most researchers simply accept the portion in the middle. Insert data in slot A and results come out of slot C. The model must hold true to the data discovered in the first moment. The researcher must depict each element accurately within the model. Sufficiently modeling all four of the elements according to the data gathered in the first moment, the second moment would be sufficiently satisfied.

The third moment of ethnostatistics is a study of the rhetoric or persuasive presentations of the research. In this moment, the researcher seeks to persuade the audience that the research design and data sufficiently illustrate the study process or relationship. In this moment, the analyzation of the previous moments work takes place. In this moment, specific assumptions that differ from the first moment must be justified. This justification must transpire prior to the results being accepted. Any difference must be scrutinized before results are given. Failure to communicate or examine the differences between the first and second moment force questions about any results. Finally, the presentation of results takes place. The results must represent only the depth and breadth found in the first moment specifically, but should include the second moment also. Recall that this presentation should not include evasive, divisive, or deception rhetoric, as doing so would immediately call into question the results.

Specific attention to each moment of ethnostatistics and to the highlighted elements of storytelling provides a useful program for the inclusion of humans in ABM. As each moment is developed, the researcher can be sure that the allure of quantification has not overwhelmed them. The researcher knows by following the storytelling threads through each moment that indeed control does not rest with the computers.

## AN EXAMPLE

Perhaps the best method of explaining the theory developed here is to give an example from a published article using computer simulation. This example is neither an endorsement of the article or a denouncement but merely an example of the usage of this theory.

Dynamic Capabilities and the Emergence of Intraindustry Differential Firm Performance: Insights from a Simulation Study (Zott, 2003) published in the Strategic Management Journal. This article looks at a difficult question for strategic management researchers. The question of "Why are firms different?" eludes researchers despite much empirical and theoretical effort to answer that question (Rumelt, Schendel, and Teece, 1994). Economic theory predicts that differences between firms particularly competitive firms will dissipate if not completely eliminate over time, but empirical evidence shows this not to be true (Zott, 2003). Citing several key studies with empirical evidence, Zott introduces us to the main theme of his study. Namely, the question, "Why do firms in the same industry perform differently?" (Zott, 2003).

### First Ethnostatistical Moment

According to the theory established earlier in this paper, the theme is the why of storytelling. The theme in the first ethnostatistical moment establishes the understanding of why this is necessary. Although, Zott does not go to great lengths to provide a deep understanding of the why, it is sufficient for two purposes. First, the theme will be an ever present theme behind everything that this study seeks to provide. Secondly, Zott's study appears in an organizational strategy themed journal, where the

background and deep understanding of the why is understood by the readership with only small reminders.

The theme introduces the plot of this moment of the study. Since the theme is the why, the plot provides us with the what based on the theme. In this the first ethnostatistical moment of the Zott study, the what involves the firms within a particular industry and their respective performances. More specifically, the relationships between firms in the same industry that differ based on dynamic capabilities and between those dynamic capabilities and firm performance. Although the characteristics of the dynamic capabilities have been theorized and studied, the affect of those capabilities on firm performance within an industry support the theme of the study. Zott devotes a section of the paper to further exploration the rationalization of those relationships.

Similar to the introducing the plot, the plot introduces the actors. The actors in the first ethnostatistical moment at first glance are firms and firm performance. Recall that actors are the ones involved in the plot. It is important to note that one actor is not, according to this ethnostatistical moment, simply individual firms in the same industry but rather the bundle of capabilities that each individual firm may integrate, build, and reconfigure to address a sustainable competitive advantage. According to Zott, since all firms have access to similar resources it is the dynamic capabilities which allow firms to compete within the same industry. Therefore, one of the actors is not the individual firm but the individual attributes of the dynamic capability that exists within the individual firm, namely costs, learning, and timing (Zott, 2003). Firm performance is the other actor that influences the plot. Different than individual firms as actors, firm performance is the actor with characteristics encompassing product innovation, process innovation, and costs.

The frames are the boundary conditions that establish the context in which the plot can be accomplished. While many times the frames are explicitly stated, in Zott's development the frames are not. However, the implicit frames can be developed to allow the plot to develop. First, while individual firms are not the actors in the story, they do provide a boundary condition. Namely, that each firm must have access to the entire resource configuration and that the actors and their relationships are under study. If any firms had an unattainable access to resources then the relationship and therefore the plot could not be reached. Secondly, the actors themselves could be held distinct enough to be measured. Zott does acknowledge that the actors do interrelate to each other, so this will be a difficult boundary to maintain.

The first ethnostatistical moments draws these unique story characteristics; a theme of firms in the same industry performing differently, a plot of relationships of the dynamic capability construct between firms and performance, actors of cost, learning, and timing, and firm performance, and finally frames of the access to the same attributes (being in the same industry) and these attribute being distinct. Identification of these aspects provides a smooth transition to further development in the first ethnostatistical moment.

**Second Ethnostatistical Moment**

For the purpose of this theory development, the second ethnostatistical moment is the most important. The second ethnostatistical moment involves the construction of the data. In the Zott paper, creation of the data takes place within a computer simulation model. Therefore, an investigation of the construction of data through computer simulation will determine if computer simulation can be move from theory development to experiment.

One of the more important aspects of the second ethnostatistical moments are the actors. The first actor developed in the Zott article is that of firm performance. Recall that firm performance evolves from product innovation, process innovation, and costs. The creation of the product and process innovation comes from the quadratic relationships from the theory development. The reader is left to believe in the formulas established for these two pieces of the firm performance. The third piece, total production costs, comes from the inverse relationship of accumulated efforts to the reducing costs. This relationship also yields a formula based on the theory development, putting the quadratic formulas and the production cost formulas into an objective function of a demand function based around a competition theory. The development of this formula is spelled out in great detail. While the formula looks very involved, the

step-by-step derivation of this formula makes it seem much simpler. The reader is left to accept the creation of data for the actors of this moment. The development of these actors is important for the support of this study.

The next aspect that becomes apparent in the second moment is the boundaries. The boundaries in the second moment assure that the actors can perform the plots and portray the themes. The boundaries for the computer simulation involve the assumptions for the programming of the model. These assumptions provide the model with the boundaries conditions in which the actors perform. In the Zott article, these assumptions can be found in Appendix 2 (Zott, 2003). These assumptions should be evaluated for soundness in providing for a realistic model. Several of these assumptions are for convenience sake (i.e., 200 simulation periods, experimental change of 5%, instantaneous selection of variables, etc.). Other assumptions show the formulas for each actor that aid in the realism of that formula (i.e., fitness values for profits from selection, rationalization rules for pricing based on competition, etc.). These assumptions set the boundaries for the creation of data in this second moment.

The plots, in the second ethnostatistical moment, model the explicit relationships and check for any implicit relationships. In Zott (2003), the plots for the second moment can be found in one particular section of the article. In that section, Zott suggests a priori propositions for each of the relationships. Zott "maps" these relationships for different stages of the model. Using theoretical underpinnings, Zott attempts to show how each of these relationships model the focus of a set of the characters (each stage of the original model) to firm performance. For instance, the timing of resource deployment or the retention actor fosters differential firm performance due to stochastic (selecting to change a percentage of the time and not to change the inverse percentage of time) or due to suspected performance improvement reasons. This one relationship can support the plot explicitly as stated in the proposition or implicitly be influence by another actor as noted in the footnote. As shown by this example, the plots establish the relationships between the actors. However, the key for validity for the reader, in the second moment, is in showing each of these relationships and understanding how the relationships are being created. Zott has done so with his development of propositions or plots.

The final piece of the storytelling puzzle involves themes. Themes in the second ethnostatistical moment measure out the decision points and show the modeling of those points. Once again, Zott sets a section of the paper aside to establish this portion. In fact, he states, "at this points, it is necessary to verify the logic and soundness of the conjectures developed in the previous section and test their robustness by simulating the model introduced earlier" (Zott, 2003, pg. 109). In making this statement, Zott goes directly to the point of storytelling themes for this particular moment. The model will hold each plot, or relationship, as either on or off allowing for it to affect the model. In doing so, Zott suggests that everything, except for the decision point in question, is held identical for the modeled firms. This allows for the decision points to be encompassed in the plots to be studied.

**Third Ethnostatistical Moment**

The third ethnostatistical moment, deals with the relevance of the output or the results of the second moment. This moment is typically the most important portion of the study as the benefits of the study are illuminated. In the Zott paper, this is of particular importance because the author also needs to interpret what the output depicts because it is not as straightforward as other statistical methods for researchers.

Zott handles each of the plots, or relationships, individually to suggest the importance of each pattern depicted by that relationship. In doing so, Zott first looks at the themes of each relationship. The themes are the patterns found from the model. Zott labels these as impacts on each individual plot, or relationship. Most of the impact sections refer to the corresponding figure showing the firm performance over time as each firm is affected by the relationships of the other actors. This discussion leads to a discussion of the importance of each relationship as a matter of its implication towards theory. Taking both the theme and the plot together underscores the importance of each individual actor on the actor of firm performance. Zott also gives an update to the relationships (propositions) established in the second moment. Several of these relationships needed to be modified based on the results of the computer simulation.

Interestingly, Zott chose to also explain several of the characters with the individual relationships. The characters in the third ethnostatistical moment involve the generalizability of the characters. After establishing the themes and the frames, the theoretical consistency shows the influence of the computer simulation on the patterns of the characters and thus the effect of the characters is also explored at this time.

The final piece of the storytelling puzzle in the third moment is the frames of this study. The frames in the third ethnostatistical moment deal with the generalizability of patterns across different contexts. Zott does mention in his conclusion that the actors and their patterns do show some interaction, and that the benefit is not sustainable as the firms tend to move towards equilibrium. He also mentions individual relationships that affect some change. To his credit, Zott also acknowledges limitations of his study, and therefore a limitation of computer simulation in this particular instance. These all contribute to the generalizability of the study.

## CONCLUSION

Computer simulation as a means of scientific research, particularly in Business Research, is becoming increasingly popular (Mezias & Eisner, 1997). However, understanding wresting the experimental control from the computers is important and a central theme to this theoretical development. This paper develops a means by which a computer simulation study can be reported and understood through the use of storytelling and ethnostatistics. An example of how this theory could be used was also given.

After the example, several key conclusions become apparent. First, a computer simulation must be very explicit if it is to reach the status of other empirical study methods. The theoretical development must move seamlessly through to the creation of the data through simulation methods, and then finally to the understanding of the results. The elements of storytelling provide a focus for such a transition.

Secondly, evaluation of all empirical studies can be done through the lens of this theoretical development. Through the evaluation of these elements and a segregation of the three moments of ethnostatistics, researchers can have a framework through which to evaluate a study.

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