

A COMPLEX ADAPTIVE SYSTEMS VIEW OF RESILIENCE IN A PROJECT TEAM

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ABSTRACT

This research paper follows the theoretical paper, *Group Development: A Complex Adaptive Systems Perspective* (Edson, 2010) presented at the 54th Meeting of the International Society for the Systems Sciences in Waterloo, Canada. This case study explored resilience in a project team through analysis of group development from a complex adaptive systems perspective. Three research questions focused on the team's consciousness of a need to change under adversity, its response through adaptive action, and its potential for innovation through creative destruction. The study used flexible design and mixed methods by applying grounded theory coding techniques to understand a retrospective case study. The subject was the CUSD2009 Team of approximately 200 students and faculty members, which designed and built a solar house over a 2-year period for an international competition with 19 other teams sponsored by the U.S. Department of Energy. Data analysis used a multilevel approach consisting of coding the data through the lenses of two models and a theory. Relationships between models of group development, the complex adaptive cycle, and complex adaptive systems theory were established theoretically and empirically. Results of the 3 research questions indicated that the team exhibited agency through the following: (a) collective consciousness of a need for change to maintain the team's function toward the project goals, (b) collective action to make necessary changes, and (c) emergence of innovation through creative destruction entailing renegotiation of group norms in response to an adversity. The multilevel analysis culminated in an integrated systems perspective with conclusions about resilience in project teams, specifically the role of environmental feedback. Implications for future research using complex adaptive systems as a theoretical foundation for studying group development and resilience include organizational culture, inflection points, nested adaptive cycles, emergence of leadership, and emergence of innovation. This research contributes a deeper understanding of project team resilience in organizational systems such as companies, non-profits, governmental, and non-governmental entities by revealing the importance of environmental feedback and organizational learning to build adaptive capacity.

Keywords: Complex Adaptive Systems, Group Development, Panarchy, Creative Destruction, Project Teams, Leadership, Innovation

INTRODUCTION

Overview

As a project manager for several technical project teams, I observed that some project teams were adept at overcoming adversity, while others were not. The project teams that adapted to environmental constraints were able to modify their functions to meet goals. These observations compelled me to investigate the nature of project team resilience in the face of adversity. Based on my experience, my sense is that project teams present an untapped resource for understanding adaptation and a leverage point for transformational change in organizations.

As individual human beings in a complex world, resilience is a trait and a process that helps us continue to function in the face of adversity (Adger, 2000; Jacelon, 1997; Read, 2005). If resilience is important to us as individuals, does it have the same value in groups? If so, how do we know? Understanding how groups develop and evolve has been the subject of studies by organizational behaviorists and operations researchers since early in the 20th century (Robbins & Judge, 2007). Group development comprises the stages and processes a group goes through in its life cycle (Schermerhorn, Hunt, & Osborn, 2000). Group development research continues to inform organizational leaders as they acknowledge the potential teams have in organizational learning and the achievement of objectives (Chan, Lim, & Keasberry, 2003). High performing teams are sources of intellectual capital (Ulrich, 1998). From early research, many models have been developed to explain what we can expect in typical group development (Hill & Gruner, 1973). However, what happens when a team encounters adversity? How is the group's development impacted? What can we learn about group adaptation to adversity that will help our organizations become more resilient?

Purpose

The purpose of the research was to discover how project teams (teams working together for over a year toward specific goals and objectives of a single project or program) adapt to adversity (unanticipated events that impact the team's ability to meet its goals and objectives) and develop resilience (adaptation that supports successful achievement of goals and objectives, as well as learning for future planning and preparation). In addition, the study's aim was to learn their process of change and whether it can help build team and organizational resilience. The objective of this research study was to develop an understanding of how project teams renegotiate group norms to adapt to new environmental constraints.

This case study documents the group development of Cornell University's Solar Decathlon 2009 (CUSD2009) Team (project team), which faced a \$60,000 shortfall in its project funding (adversity), to discover patterns of behavior, processes, and events for evidence of adaptation and resilience. Specifically, this research study looked for the team's consciousness, which was needed to make changes in how it operated and its subsequent actions to adapt to new constraints. Further, the data collected from this study provided the basis of comparison to track the project team's experience against group development models (Bennis & Shepard, 1956; Herbert & Trist, 1953; Tuckman & Jensen, 1977), an ecological adaptation model (Gunderson & Holling, 2002), and complex adaptive systems theory (Holland, 1992, 1999).

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

Complex adaptive systems are diverse, interconnected systems that exhibit self-organization (purposeful internal evolution), hierarchy (certainty created through structures that bring order and meaning), emergence (a coherent and integrated dynamic of innovation), and learning (planned application of experience to future events) based on environmental feedback in response to uncertainty (Ahl & Allen, 1996; Ashby, 1962; Argyris, 1999; Bennett & Bennett, 2004; Corning, 2002; Gunderson & Holling, 2002; Goldstein, 1999; Holland, 1992, 1999; Lewes, 1875; Mintzberg & Westley, 1992). In this study, the data collected were analyzed for evidence of the team's experience of creative destruction (Schumpeter, 1942; Sombart, 1913), in which innovation supplants processes that no longer serve the goals and objectives of the project team.

Based on my literature review (Edson, 2010), I developed a conceptual framework about project team adaptation, creative destruction, and resilience. I sensed that the CUSD2009 Team experienced an urgent need for change upon discovery of a \$60,000 shortfall that impacted its ability to compete in the U.S. Department of Energy's (DOE) Solar Decathlon (2009) in Washington, DC. This realization prompted rapid evaluation of the team's status and options. In order to meet the challenge, the team took action to alter how it operated by setting aside norms that no longer supported the team's goals and objectives. Further, the team exhibited creative problem solving skills to address the gap between where the project stood and its goals. Team learning occurred when established processes and norms were no longer practiced and new norms were implemented, a type of creative destruction (Schumpeter, 1942; Sombart, 1913).

The case study revealed that the conceptual framework for adaptation has merit for further research. The data analysis showed that the project team's experience of overcoming adversity is analogous to a nested adaptive cycle of creative destruction resulting in resilience. The research explored the nature of adversity, adaptation, resilience, and organizational learning in project teams as a single case study.

Approach

This research study incorporated a dual approach of case study (Yin, 2003) and grounded theory (Charmaz, 2006; Strauss & Corbin, 1990, 1998) methods. This case study was retrospective (reflective on past events) and revelatory (providing insights from reflection and appreciative inquiry) (Cooperrider & Whitney, 2005; Yin, 2003). According to Yin (2003), a justified rationale for conducting a single, revelatory case study is when a situation exists in which "an investigator has an opportunity to observe and analyze a phenomenon previously inaccessible to scientific investigation" (p. 42). In this case, the subject project team's experience had not been studied, yet the team was considered a model by faculty and the administration for multidisciplinary projects at the university in the future. The CUSD2009 Team's experience provided insights otherwise unknown that may prove valuable to future project teams sponsored by the university based on this model.

Once the data were collected using interviewing procedures (Kvale, 1996), they were coded using case study (Yin, 2003) and grounded theory (Charmaz, 2006) methods. It was then analyzed using a theoretical framework of complex adaptive systems and its principles of self-organization, hierarchy, emergence, and learning. The research is based on an isomorphic understanding of group development in human systems and its relationship to adaptive cycles in

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

complex adaptive systems theory used in ecology. Byrne (1998) defines isomorphism in the context of complexity theory in the social sciences,

This term applies at the point where ontology and epistemology meet in practice in any scientific description of the world, although it is most usually applied in relation to quantitative description. A description and the world are isomorphic when the elements of the description correspond to entities in the real world and when the rules describing the relationship among elements in the description correspond to actual relationship among entities in the real world. The quantitative consideration of isomorphism depends on the transformation of uninterpreted into interpreted axiomatic systems. Abstract mathematical systems in which the terms in equations have no meaning outside the mathematical system are “uninterpreted axiomatic systems”. When the terms in the equations are considered to describe real entities and the relationships among them, then the system is interpreted and is only valid if the abstract mathematics are isomorphic with reality. Usually this sort of discussion is conducted in relation to measurements at the ratio scale level and the generation of law like rules taking the form of equations, but it is equally applicable to simple typology generation and the representation of reality, not through equations, but the geometrical depiction. (p. 173).

In this research study, I suggest that a group development model (Tuckman & Jensen, 1977) and a model of complex adaptive cycles (Gunderson & Holling, 2002) serve as the theoretical frameworks for understanding the group dynamics from an organizational systems perspective. I suggest this because they exhibit a detectable correspondence and symmetry through the principles of self-organization, hierarchy, emergence, and learning. Case study (Yin, 2003) and grounded theory (Charmaz, 2006) serve as the methodological frameworks for the research design, data collection, and data analysis.

Research Questions

The study focused on three research questions. First, when faced with adversity, how do project teams, specifically, the CUSD2009 Team, recognize and acknowledge that their current operating processes (e.g., norms) no longer support the attainment of their objectives? Second, how do project teams, specifically, the CUSD2009 Team, renegotiate those processes (change) so new operating processes can emerge that support their progress and objectives? In other words, these two questions ask about how project teams become conscious of the need to change and how they take action to change their form in the face of adversity so they can continue to function. Third, does the project team’s, specifically, the CUSD2009 Team, adaptive experience follow a pattern of the nested cycle of creative destruction? These questions are important because they relate to agency, which is a distinguishing factor of resilience in human systems as opposed to ecological systems that function within time and space scales. Human systems add meaning making (Vickers, 1968; Weick, 1995) to the factors influencing resilience, while ecological systems do not. As the orator Robert Ingersoll (1833-1899) observed, “In nature there are neither rewards nor punishments; there are consequences” (p. 34). Agency is a form of meaning making that influences decision making and action. If human systems operated from an entirely rational basis, then it may be assumed that human adaptation would follow similar patterns of adaptation; however, human systems do not act in entirely rational ways (i.e., the fallacy of rationality). This study explores agency as a critical distinguishing factor in understanding resilience in human and complex adaptive social systems.

Definitions

Before explaining the theoretical foundation for using group development and complex adaptive systems models, it is important to define the terms and scope of this study. In *Group Development: A Complex Adaptive Systems Perspective* (Edson, 2010), definitions of resilience and adaptation were defined, along with adversity; organizational culture; norms and norming; and organizational learning and transformation. The theoretical foundation of this research was detailed, as well as the system context, based on a literature review that compared and contrasted the two models and the theory. Readers are encouraged to review the theoretical paper to gain greater understanding of the research study design and the results.

Focus and Theoretical Foundation

This research applied complex adaptive systems theory to group development by designing a research project that used the former to inform the latter. The primary underlying systemic principle for this research was that resilience entails a system's adaptation of its form in order to preserve its function or "form forever follows function" (Sullivan, 1896). For example, in architecture or software development, the client's functional needs drive the design of a building or a computer program. Secondly, feedback gained through reflective dialogue and evaluation, or double-loop learning (Checkland, 1999), supports systemic resilience. For example, organizations that respond to customer feedback and self-evaluation by altering their processes and inculcating new employee behaviors to meet client needs act on the lessons learned, a type of organizational learning (Argyris, 1999).

From my observations in this study, systemic adaptation requires willingness to listen to environmental feedback (flexibility) and to incorporate change into the system (versatility). Continual flexibility and versatility in using feedback increases adaptive capacity and, when combined with double-loop learning, becomes resilience. We may intuit that adaptation occurs as such in human systems; however, ecological adaptation illustrates some compelling examples of adaptation based on scientific study (Gunderson & Holling, 2002).

Gunderson and Holling (2002) have developed a dynamic model of ecological adaptation that includes four processes. The four processes are (a) rapid growth/exploitation, a process of utilizing resources to promote growth; (b) conservation, a process of storing energy by maximizing the utility of resources; (c) release, a process of liberating conserved resources due to an environmental event; and (d) reorganization, a process of capturing opportunities for the next adaptive cycle starting beginning with a phase of exploitation. Gunderson and Holling developed this model based upon research done in boreal coniferous forests in the Northern Hemisphere and they extend it to social, economic, and political systems.

While the adaptive cycle's four processes (Gunderson & Holling, 2002) offer several opportunities for research, the compare/contrast analysis (Edson, 2010) of the two models of group development and ecological adaptation revealed inflection points between each of the four phases. These transitions present possible leverage points for transformative change (Jarman & Land, 1992). Specifically, the inflection point between conservation (hierarchy) and release (emergence), also described as "creative destruction" (Schumpeter, 1942), presents an intriguing aspect of group development that may be worth investigating. This point is compelling because

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

of the tension between hierarchy building (norming) and emergence through the renegotiation of group norms when a project team discovers that their operating structures no longer serve or support the attainment team's objectives. This point specifically addresses perennial questions in organization development and organizational behavior about how change occurs and how transformation effectively happens.

This case study explored the gap in our understanding of expected group development under normal circumstances with that of group development under stress, using a complex adaptive systems perspective, which is used in ecological systems. I explored and discussed a comparison between existing models of group development (Bennis & Shepard, 1956; Herbert & Trist, 1953; Tuckman & Jensen, 1977) and a model of complex adaptive cycles (Gunderson & Holling, 2002) to gain deeper understanding about the processes of organizational resilience. In effect, I applied a model used in ecological systems to human systems or complex adaptive systems to complex adaptive social systems, which are comprised of "interacting, thoughtful (but perhaps not brilliant) agents" (Miller & Page, 2007, p. 93). By examining group development through a lens of complex adaptive systems, I delved deeper into existing theories grounded in organizational behavior, operations research, and organization development to further inform my understanding of groups and teams that experience adversity.

The application of complex adaptive systems theory to group development is relatively new. In the last 10 years, complex adaptive systems theory has been suggested as a constructive way to view groups by researchers (McGrath, Arrow, & Berdahl, 2000). Researchers in organizational behavior and development have come to understand that the scientific method, while valuable in many ways, has been limiting. McGrath et al. state,

Much of that work, in line with a positivist epistemology that emphasizes control and precision and favors the laboratory experiment over other data collection strategies, has also tended to treat groups as though they were simple, isolated, static entities. Recent research trends that treat groups as complex, adaptive, dynamic systems open up new approaches to studying groups. (p. 95)

McGrath et al. (2000) call on researchers to use complex adaptive systems theory as a basis for conducting research about groups and teams. This research study responded to the call to use complex adaptive systems theory as a framework for viewing group development, specifically using a model of complex adaptive cycles.

Research Design

This section explains the research design, methods, data collection, and data analysis used to conduct the study. I examined several research approaches for conducting studies using inductive methods because there are no established systems research methods. I wanted to use methods that would allow the emergence of a narrative to inform our understanding of relationships between complex adaptive systems and group development under adverse conditions. Using more than one research approach in qualitative research is known as flexible design; specifically, using case study and grounded theory is generally accepted (Robson, 2002). As a result, this study involved two methods—the case study method (Yin, 2003) to investigate a project team's development and grounded theory techniques (Charmaz, 2006; Strauss & Corbin

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

1990, 1998) to analyze its adaptation. The dual approach was implemented because inductive reasoning, which is the basis of grounded theory, enabled me to view the CUSD2009 Team's experience as it happened, without preconceived hypotheses. The voices of the participants would clearly be heard through the data analysis and presentation.

The theoretical framework informed the design of this study, particularly the research and interview questions; however, care and caution guided the design so that the case truly reflects the team's group development and dynamics as the team members experienced it. Case study method (Yin, 2003) provided a methodological structure for the research study through the comparison and contrast of two models related through a theory. Once the case study was validated, synthesis of the data revealed emergent categories of themes related to resilience in organizational systems using grounded theory coding techniques (Charmaz, 2006).

Data Collection

I used case study (Yin, 2003) data collection procedures, as well as grounded theory techniques, as outlined by Charmaz (2006), based upon Glaser's work (1978, 1992) during the study. These procedures included collecting archival documents, conducting interviews, making direct observations during interviews, and compiling field notes. Interviews were the primary vehicle for data collection, supported by direct observations and field notes taken during the interviewing process. The interview format is based on Kvale's (1996) seven-step approach as follows: 1.) thematizing, 2.) designing, 3.) interviewing, 4.) transcribing, 5) analyzing, 6.) verifying, and 7.) reporting. The interviews were approximately an hour in duration. For this study, the interviews were conducted face-to-face, by telephone, via SKYPE, and by email. The interviews were audio-recorded using a digital recorder with a backup procedure by computer recording. All communications have been tracked through an email program and archived. I kept field notes and a log to document my observations and impressions of group environments and dynamics.

Individual interviews (Kvale, 1996) allowed for personal reflection and sharing of personal perspectives that would not be revealed during group interactions because personal disclosure may cause individual and group discomfort. The interviews provided valuable insight into the development of group processes and how individual desires were subjugated within groups. The interview questions were designed to elicit interviewee reflections about the team's dynamics at an inflection point. The questions were grounded in appreciative inquiry (Cooperrider & Whitney, 2005) and group development theories.

Interviews opened with the identification of interviewees by their roles and how they evolved during their experiences as members of the CUSD2009 Team. The following interview questions are shown as they relate to the three research questions as follows:

Research Question 1: When faced with adversity, how do project teams recognize that their current operating processes (e.g., norms) no longer support the attainment of their objectives? Interview questions ask interviewees to reconstruct in their memories of the events and their impressions about the team's discovery of the adversity and its response. The interviewees may or may not recall how the adversity was discovered or how it was addressed. The team may or may not have recognized that their current processes did or did not support the

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

attainment of their goals. This line a questioning reveals the consciousness of the group about the adversity it faced and how it evaluated the situation. It may or may not decide to change. The interview questions corresponding to this research question are:

- a. When did you feel that the team came together and hit its stride towards meeting its goals? What team event demonstrated this to you?
- b. When you learned that there was \$60,000 gap that needed to be bridged in order to compete in Washington, DC, what happened?
- c. How did the team handle the news?
- d. Did something need to change?

Research Question 2: How do project teams renegotiate those processes (change) so new operating processes can emerge that support their progress and objectives? Interview questions ask interviewees to reflect on how the team evaluated the situation and took action to make changes. These questions point to the nature of the norms and processes that are renegotiated, so that new and/or improved norms and processes can emerge.

- e. How was that change decided?
- f. How was agreement obtained to make the change?
- g. Were alternative courses of action discussed?
- h. What actions were taken?
- i. Did the actions address the situation?

Research Question 3: Did the CUSD2009 Team experience follow a pattern of the nested cycle of creative destruction? Interview questions ask interviews to reflect on the lessons learned by the team and personally. These questions go to the completion of the nested cycle of creative destruction, when the team has renegotiated processes and learned to adapt, thus emerging with innovative solutions that enable the team to meet its goals and objectives.

- j. How did the team emerge from the challenge?
- k. Do you think that the team handled this situation effectively?
- l. What have you learned from this experience that you will apply in another team project?
- m. Do you have any final thoughts that you would like to share?

These questions elicited reflections by team members of their experience of the team's adversity, how the team became aware of the situation, how the team addressed it, and what was learned. In addition, the team member's impressions about how well the team addressed the adversity and what could have been done better, and the lessons learned may emerge.

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

Data were collected and transcribed personally. The transcripts were loaded into a hermeneutic unit (file) in atlas.ti (QDAS). Once the case was validated against CUSD2009's chronological history (Werner, 2009), the transcripts were coded using grounded theory techniques of open coding, axial, and then selective coding.

Data Analysis

When I initiated this research study, I had some ideas about potential relationships between group development, ecological adaptation, and complex adaptive systems. While classic grounded theory assumes no theoretical foundations, I used grounded theory methods as a way to open the possibilities of understanding how these three paradigms might relate to one another. By using this approach, I was able to develop a multilevel analysis to view the data.

Open and axial coding was used at a first level of analysis. Data analysis began with open coding the interviews and using constant comparison with concepts from organizational behavior and anthropology of groups to gain an understanding of the processes CUSD2009 used to build the Silo House. I verified my understanding with the chronological development of the project team (Werner, 2009). Once I understood what happened and saturation was established, axial coding interconnected behavioral and anthropological categories, including agency.

Upon completion of initial coding and memo writing, the data were examined for correspondence with group development concepts. At a second level of analysis, selective coding developed a narrative corresponding to Tuckman and Jensen's (1977) model. It also verified CUSD2009's progressive manifestation of Tuckman and Jensen's longitudinal model of group development.

At a third level of analysis, axial and selective coding revealed correspondence of CUSD2009's group development processes with Gunderson and Holling's (2002) model of the complex adaptive cycle, as well as complex adaptive systems theory. While there were some similarities and sub-processes identified, distinctions between the two models were clarified. Specifically, the group development model focuses on internal processes while the adaptive cycle model focuses on processes in response to the external environment. This distinction relates to two of the research questions. It highlights the role of feedback, specifically scanning the external environment, which project teams need for higher awareness (consciousness) and response (action).

Through this process, a fourth level of analysis revealed emergent categories that correlated to terms and concepts in organizational systems, specifically, organizational culture, change (inflection points and nested cycles), leadership, and innovation. At this level of analysis, the third research question was explored in greater depth, as the phenomenon of creative destruction was revealed through several dynamics. The multi-level analysis provided the foundation for the development of an integrated systems perspective.

Validity and Reliability

This research study was conducted in conformance with two research methodologies—case study (Yin, 2003) and grounded theory (Charmaz, 2006; Strauss & Corbin, 1998). Validity is expressed through construct, internal, and external validity. During data collection, construct

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

validity was accomplished through the use of multiple sources of data, such as interviews, the project leader's master's thesis, the project manual, the project team's website, and the tour guide training manual. In addition the team's documentation, I referred to published articles about the project team and the competition, both in print and online. A chain of evidence was established through the interviews with not only student team members, but with faculty team members as well. The latter process included individual and focus group interviews. Interview transcripts were distributed to the study participants for their review and comments.

Internal validity was established through pattern matching using the two models and theory, as well as the chronological account of the team's history. Explanation building was done through two processes, the first, which included the grounded theory method of coding and memo writing and the second, which included narrative construction based upon the data results and data base queries. External validity was established through the application of complex adaptive systems theory namely self-organization (Ashby, 1962), hierarchy (Ahl & Allen, 1996), emergence (Ashby, 1962; Mintzberg & Westley, 1992; Wheatley, 1994), and learning (Argyris, 1999).

Reliability was established through the application of case study protocol through repeatability that would develop the same results. The protocol was documented using a logbook, Microsoft Project® and a QDAS, atlas.ti. The development of a case study database, which in this study was a hermeneutic unit, was completed in atlas.ti.

Limitations and Delimitations

According to Pajares (2007), limitations are potential weaknesses of the study in its design (theoretical foundations and method), conduct, analysis, sample, and threats to internal validity (bias) that were impossible to avoid or were minimized. Delimitations specify how the study was narrowed in scope and how it is bounded. Assumptions are suppositions based on research discussed in the literature review and applied in this study as foundations for the analysis and synthesis of the findings.

Limitations. Choices concerning theoretical foundations for the study created limitations. This study is based on a model of group development and a model of ecological adaptation interwoven by complex adaptive systems theory. There are other models and theories that could be used; however, I chose models that have been broadly accepted in their respective disciplines. Other models may provide different results and provide different insights into team resilience.

Design and method. Choices concerning the methods used in the study resulted in limitations. In this instance, a case study was inductively developed using open, axial, and selective coding to identify and validate group development and adaptation in a project team. In classical applications of grounded theory (Glaser & Strauss, 1965, 1967, 1968), literature reviews, development of theories before or during coding, audio-taped interviews, and discussion of the data are not permitted because it is intended to be purely inductive research. In order to investigate what could be learned from complex adaptive systems that could apply to group development, it was necessary to create a framework for designing the study. Conducting a purely inductive study using classical grounded theory methods would neither address the

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

research questions with sufficient specificity nor provide relevant results. As a result, the interview questions were derived from group development and complex adaptive systems processes including panarchy. They were constructed so that the topic was presented and left open for interviewees to reflect and respond based upon their team experiences.

Conduct. Some researchers may find qualitative data analysis software tools useful, yet, they can be limiting. In this study, QDAS, specifically atlas.ti, served as an organizational tool to manage interview transcripts, to document coding, and to facilitate the memo writing process (Muhr, 2004). I manually coded each transcript. Atlas.ti was not programmed with any standard logic and it did not “auto-code” the transcripts. There was no automatic analysis performed through atlas.ti. To maintain my immersion in the case and report results accurately, the analysis was done as if I had used paper files.

Analysis. This is a single case study that was conducted in an academic environment. Despite the focus of the project team on solving real world problems, generalizations from this case to other applications should not be drawn directly. However, the results provided sufficient foundation for further research using multiple case study and other systems research methods to examine group development based in complex adaptive systems theory. Additional rival explanations and alternative theories need to be considered, as the conclusions that were presented do not represent absolute validation, which is characteristic of grounded theory research. In this instance, using combined research methods proved to be a strength that balanced some of their individually inherent weaknesses. To overcome analytical limitations that may be inherent in using atlas.ti, I remained close to the data by personally transcribing the interviews, using a combined methodology for data collection and analysis, and performing a multilevel analysis that broadened the perspectives from which the data was viewed.

Sample population and setting. While the population used for this research was comprised of students in an academic environment, as opposed to employees in a corporate environment, it also provided insights into how self-managed and self-directed teams can create value in terms of organizational learning and innovation for their organizations. CUSD2009 was a student led effort, not faculty directed. As a result, the students were granted more flexibility to assume risk, make mistakes, and learn from them than they would at most traditional organizations. In addition, the university administration had not fully endorsed the project, so the students were required to secure funding through other resources.

Some critics may view the context of the project (academic), its participants (faculty, students), and its context (self-directed and self-managed team, sustainability model application) as limitations which have little application in the “real world.” I disagree. The lessons learned from project teams that are granted opportunities to take greater risks may provide insights into the potential innovations and value when leaders empower their teams.

Threats to internal validity: Researcher’s role and ethics. Internal validity is threatened when the results of a study may be manipulated. As part of my role as a researcher, I believe that not only a systemic, but systematic approach to conducting this research was required. The processes of coding and analysis followed the structure presented in the literature review closely. To understanding my role in terms of influence, bias, and ethics, an important principle can be

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

borrowed from action research: that the observer impacts the observed is a basic tenet of action research. Stringer (2007) notes,

Problems do not exist in isolation but are part of a complex network of events, activities, perceptions, beliefs, values, routines, and rules – a cultural system maintained through the life of the group, organization, or community. As people reveal relevant details of their situation, they see more clearly the ways in which the research problem or focus is linked to features of their organizational, professional, and/or community lives. This disclosure leads people past their taken-for-granted perspectives and promotes more satisfying, sophisticated, and complete descriptions of their situation. (p. 67)

The same principle applied to this research study based in case study and grounded theory because it relied on inductive reasoning. As a result, in the role of researcher, I remained reflective throughout the study. I maintained a journal (logbook) of my thoughts, recording my personal reflections and thus, capturing some of my biases.

I was mindful of personal factors that contribute to bias during the course of the study based upon my experience during the pilot study, prior research, and employment. Some of these personal factors are: (a) education; (b) gender; (c) socio-economic status; (d) assumptions and beliefs about adversity and resilience; (e) values and value judgments; (f) national and professional culture; (g) organizational preferences; (h) beliefs about what is positive versus negative, duality, and responsibility; (i) prior experiences and knowledge about organizational culture, adversity; (j) resilience, and systems; (k) expectations about processes, competencies, and study results. Each of these factors had potential to influence the data collection and analysis.

Further, I carefully relied on the inductive nature of the research design to reveal truths during the data analysis and not to introduce my personal experience into the analysis. To minimize the impact of these factors on the research process, I used a journal as a central data bank for the collection of memos. I shared these reflections with my research committee chair and committee members throughout the study in an effort to keep the data collection and analysis clear of personal bias. The intent of this research was in pursuit of truth (operational realities) about team resilience and its impact on organizational systems using a complex adaptive systems framework. Further, my intent was to present data, analysis, and results as clearly and accurately as possible, given the constraints of the study.

Delimitations. The delimitations of this study, or how the scope was specifically narrowed by the choices I made as a researcher, included several considerations. As with many projects, time scales and resources were important factors that influenced scoping decisions. My experience as a project manager conducting a study to integrate multiple disciplines (human, ecological, and engineering systems) also influenced the scope of the study. As a result, the audience addressed in this study is broader than organizational systems scholars and practitioners. The audience includes technical project managers and engineering managers.

In organizational systems research, it is important to clearly define the system that will be studied. In this case, a project teams was selected because of their duration (time scale of at least one year), their focus (technical goals and objectives), and their organizational influence

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

(leverage point for transformative change). The field of groups was narrowed to project teams because project teams have enough time to progress through Tuckman and Jensen's (1977) phases of group development. Second, the study was narrowed to the inflection point of creative destruction because, of the eight possible studies that resulted from the comparison of models in the literature review, it appeared to be closely related to the development of resilience in groups. As a result, these scoping decisions necessarily excluded some factors and subsequently create some shortfalls. Other groups such as committees, task force groups, and work groups, are not included because of they typically have shorter time scales and may not experience the progression of group development. This decision limited the applicability and generalizability of the findings to groups and teams that meet these criteria.

Further, this research study focused on the project team and not on the institution in which it operated and not on past or future teams even though they are mentioned. This scoping decision was made because I believed that the study would remain focused on the project team's processes, while keeping in mind that other viewpoints may create different interpretations of events. Not only did the results indicate that further research is merited, but a team (system) cannot operate in isolation.

Assumptions. Through the literature review (Edson, 2010) some scoping decisions and concepts were established as accepted forthrightly and as part of the limitations and delimitations of this research. The following assumptions applied to this case study:

1. Adversity tests group cohesion and commitment (Bandura, 1989, 2000).
2. Group cohesion and commitment are thresholds for team performance (Paton, 2003).
3. Adversity precipitates a nested cycle of creative destruction (Gunderson & Holling, 2002; Jarman & Land, 1992; Land, 1986).
4. Resilient teams have competencies that can be learned (Coutu, 2003).
5. Tuckman and Jensen's (1977) model of group development is valid (Gersick, 1988, 1989; McGrath, 1991)
6. Gunderson and Holling's (2002) model of adaptive cycles in ecology is valid (Carpenter, Folke, Scheffer & Westley, 2009).
7. The panarchy principle of nested cycles is a useful framework for understanding the process of creative destruction (Gunderson & Holling, 2002; Jarman & Land, 1992; Land, 1986).

These assumptions were applied throughout the design and conduct of this study. I acknowledged that the applicability of the results may be limited to project teams that are similar; however, the value of investigating such a group outweighed the risk of its limited applications.

Data Presentation

Data Overview

Three research questions were developed to explore the inflection point of change and creative destruction. In this section, the results are presented numerically and qualitatively. First, a demographic summary and results overview are presented to introduce the data. Second, the summary sets the stage for a numeric view of the data results, which is explained by relating it to the qualitative data. Third, the three research questions are presented.

Demographic summary. Thirty interviews were conducted consisting of 26 student team members and four faculty advisors. The majority of interviews (18) were conducted in person, on-site at Cornell University. The remaining interviews were conducted remotely by phone (9), via SKYPE (2), and by email (1). The average length of interviews was approximately 60 minutes. The demographic profile included 80% (24) male and 20% (6) female, who represented 30% (9) Architecture/Arts, Architecture, and Planning, 6% (2) Landscape Architecture/College of Agriculture and Life Sciences, 46.6% (14) Engineering/College of Engineering, 10% (3) Business/Johnson School of Business, 3.3% (1) Communications/College of Agriculture and Life Sciences, 3.3% (1) Hotel Administration. The team participants consisted of 13.3% (4) faculty, 16.7% (5) graduate students, 70% (21) undergraduate students.

The CUSD2009 team comprised approximately 150 students at different points during its progress over a two year period from October 2007 through October 2009. A large number, approximately 75 team members, held minor roles, typically early on in the formation of the team, as researchers contributing information for decision making and receiving course credit, or later on during the competition, as tour guides performing public relations. The remaining 75 team members held various roles in leadership, sub-team leadership, design, administration, project management, construction, business, budget, fundraising, communication, and public relations. Of the 26 students interviewed, 15.4% (4) held top leadership positions, 30.8% (8) held leadership board positions, 50% (13) were sub-team leaders, 3.8% (1) held a standard team member/contributor role. A minimum of 20 interviews was proposed for this research study to achieve grounded theory saturation (Glaser & Strauss, 1968). An additional 10 interviews were conducted for a total of 30 interviews. The interview total represents either 20% of the total team (150 members) or 40% of the core team. Looking at it another way, the interview total represents 82.8% (29) of the most committed team members (35) whose tenure with the team extended through the entire 2-year period.

Numeric Results

In this section, the CUSD2009 narrative moves from interpretation and validation of the case as it related to Werner's (2009) team history to interpretation using case study combined with grounded theory methods. The transition from standard case study method begins with coding the transcripts for group development patterns based on concepts drawn from organizational behavior and anthropology. Grounded theory coding and memo writing techniques continued to be used for the next three levels of analysis based on group development (Tuckman & Jensen, 1977) and ecological adaptive cycles (Gunderson & Holling, 2002) as

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

related through complex adaptive systems theory, and finally integrated into a systems perspective.

A summary of the multilevel analysis is shown in Table 1.

Table 1. CUSD2009 Research Results: Coded Comparison of Group Development, Adaptive Cycle, and Complex Adaptive Systems Theory

Group Development Model	Complex Adaptive Cycle Model	Complex Adaptive Systems Theory
Forming (58), Storming (67)	Exploitation (47)	Self-Organization (84)
Norming (87)	Conservation (61)	Hierarchy (104)
Performing (63)	Release (42)	Emergence (78)
Adjourning (42)	Reorganization (39)	Learning (60)

This summary reflects the numeric frequency of coding that, in conjunction with the following qualitative analysis (see Qualitative Results section) demonstrates the assertions stated in the this section. The qualitative analysis interprets the coding frequencies and gives them meaning in the context of the two models and the theory. The coding results, shown in Table 1, indicate that CUSD2009 exhibited patterns of both models, as well as demonstrating the principles of complex adaptive systems. Observing the robust demonstration of the complex adaptive systems principles supported the application of the theory in making the argument in favor of using it as a bridge to compare the group development model and the complex adaptive cycle model.

The numeric results for the coding family “group development” in concert with the qualitative analysis indicated that CUSD2009 followed a pattern of phasic development described by Tuckman and Jensen (1977). The foundation of many group development models, and specifically Tuckman’s (1965) model, is largely an understanding of group psychology which was derived from studies performed at the Tavistock Institute by researchers such as Herbert and Trist (1953) and Bennis and Shepard (1956). The results of this coding family show that not only was CUSD2009 a complex adaptive system but it was a complex adaptive social system that followed the expected group development stages of Tuckman and Jensen’s (1977) model.

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

By recognizing this relationship, another aspect of the rationale for the argument in favor of using complex adaptive systems theory has been established. In other words, the results show that some adaptation takes place within Tuckman and Jensen's (1977) model of group development. The next step is to determine the extent of the adaptation under adverse conditions and the applicability of the complex adaptive cycle model in making that conclusion.

The results for the coding family "complex adaptive cycle" in concert with the qualitative analysis indicated that CUSD2009 demonstrated a pattern of adaptation that followed the complex adaptive cycle model as described by Gunderson and Holling (2002). The extent of the CUSD2009 adaptation was observed in the coding frequency. The data showed that the coding family for the complex adaptive cycle model occurred with less frequency than for the group development model or complex adaptive systems theory. This may indicate that adaptation is a subset of processes that occur within the context of group development in complex adaptive social systems.

While the frequency for the adaptive cycle coding family was less than the others, it is important to note that the patterns of frequency for the codes were in alignment with the patterns of coding family results of the group development model and complex adaptive systems theory. These results validated the notion that the two models can be related to each other through complex adaptive systems theory. The difference in frequency highlights that a one-to-one correspondence was not validated in this case and further explorations of these patterns are necessary. The results also emphasize the importance of not only comparing to discover similarities but also differences for the purposes of gaining insight into how project teams develop resilience.

A fuller understanding is gained when the numeric results are viewed in context of the qualitative analysis. In addition, the veracity of using complex adaptive systems theory and the model of complex adaptive cycles as a foundation to investigate group development of project teams under adversity becomes evident. The coding results established relationships between the two models using the theory. In the following section, the qualitative coding results for the three research questions are detailed.

Qualitative Results

A qualitative analysis of the data results was conducted to verify the theoretical foundations (Edson, 2010) and to establish a basis for analyzing the results for the three research questions. The qualitative results were derived from the multi-level analysis, which is detailed in my dissertation (Edson, 2011). Once the team's chronology and the coding foundations were validated, the interviews were coded for the processes of Tuckman and Jensen's (1977) longitudinal group development model. Thereafter, coding was done for the four processes of panarchy and the four principles of complex adaptive systems theory. I analyzed the results for evidence of a progressive narrative that revealed that CUSD 2009 had experienced processes of group development and panarchy through its adaptation to adversity. In viewing the data numerically, evidence of occurrences of these processes was shown objectively. In viewing the data qualitatively, evidence of continuous progress of CUSD2009 in its group development and adaptation was demonstrated. It is important to note that, while validating the relationship

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

between the models was an essential process conducted during the study, the focus was not on proving an unequivocal correlation between the models, but addressing the research questions.

Figure 1 illustrates how the two models and the theory related to the timeline of CUSD2009's history. It is important to note that this diagram marks progression but does not imply that the two models and theory are equivalent to one another. As a matter of fact, it

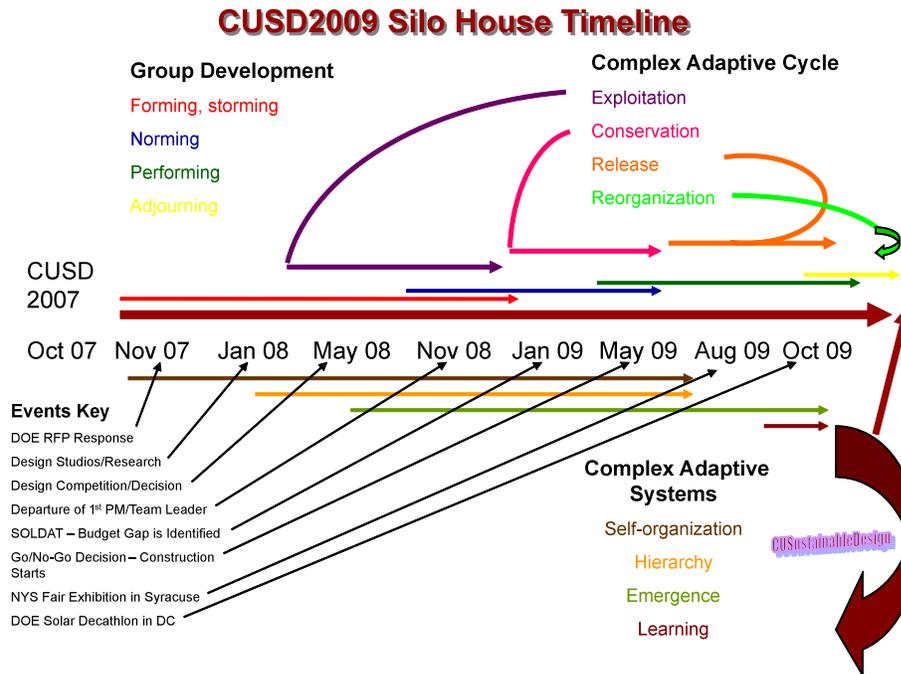


Figure 1. CUSD2009 timeline of group development and adaptation.

graphically illustrates the data results with respect to adaptive processes within group development processes and phases. The following sections present the qualitative results of the multilevel analysis with respect to the three research questions.

Research Question Results

This research focused on three research questions as follows:

1. When faced with adversity, how do project teams, specifically, CUSD2009, recognize and acknowledge that their current operating processes (e.g., norms) no longer support the attainment of their objectives?
2. How do project teams, specifically, CUSD2009, renegotiate those processes (change) so new operating processes can emerge that support their progress and objectives? In other words, these two questions ask about how project teams become conscious of the need to change and how do they take action to change their form in the face of adversity so they can continue to function.

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

3. Does the project team's, specifically, CUSD2009, adaptive experience follow a pattern of the nested cycle of creative destruction?

The first two research questions were separate codes that were tracked in a coding family called "agency." According to Checkland (1999), agency, specifically human agency, is one of the distinguishing characteristics of human organizational systems. Human agency encompasses consciousness and sense / meaning making (Vickers, 1968; Weick, 1995). This research study assumed that groups were complex adaptive systems akin to ecological complex adaptive systems; however, human agency could be a mitigating factor in how humans adapt as opposed to how ecological systems adapt. In this study, it was important to establish that adaptation to adverse conditions was done consciously and followed by purposeful action.

First research question. The results for the code "recognize need to change/ adapt" revealed that the CUSD2009 Team was conscious of the adversity (\$60,000 budget gap) by a frequency (the number of times a code occurred in the data) of 90 in 30 interviews. The following excerpts describe what happened when SOLDAT notified the team about the \$60,000 budget gap.

A lot of people were kind of half in and half out, wishy washy, not really doing too much. Yeah, you know, I think that PL1 got pretty stern with the team. He was our overall team leader and it was pretty clear that, "Look guys this is the situation. This is a real situation. This is a real gap."

One team member stated the following about the team's reaction to the news of the budget gap:

I think every subteam leader was just as concerned as we were. It affected everybody really. The whole entire team was serious, you know, because of all the work that we had gone through, nobody wanted to do that (end it). So, everybody was very aware of the situation and serious about saving money. I think that it was good to communicate the subteam leaders and the subteam leaders to their members that this was such a big situation and that we needed to refocus all our attention for these two weeks to address the issue. Time was short.

Another team member expressed the realization of the consequences of the budget gap as follows: "To go back to the budget crisis thing, we knew that if we couldn't figure this out that the project wasn't going to happen."

Second research question. In addition, the results for the code "actions taken to change/adapt" indicated that the CUSD2009 Team actively took steps to change by a frequency of 122 in the 30 interviews. The following quotes describe the outcome of the team's evaluation as actions toward better bookkeeping through the rest of the project. One team member stated, "So that is when PL1 start having these meetings on Sunday's where we met for an hour or so for a couple hours talking about finances, talking about progress of the project." Another team member stated the following as actions taken in response to the gap:

In that evaluation, the bookkeeping that hadn't been done previously but only really started at that point, it really emphasized the need for it and from that point on we would enforce that kind of bookkeeping throughout the rest of the project. It was too keep us on track.

Another team member expressed the team's actions in response to the gap as follows:

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

Well, it is documented in terms of how things unfolded and from that point because what happened is that SOLDAT did come to us and said, “Well, now you have this challenge. If you want a build the house, you need to come up with X amount of dollars. And, we set a price that we were shooting for. I think we wanted to have \$60,000, I think we determined that we needed an additional \$60,000 of material and in kind donations. And, what happened is the committee team members started making phone calls - begging and pleading and asking everybody that we knew and all these companies that had been working with us,” “Is there any way we can get a discount on this, is there any way we can get this for free?” And, with that giant push we got the results we were looking for. We did get a lot of material discounts and in kind donations and that’s how we were eventually able to meet that goal.

Third research question. The third research question, which focused on creative destruction as a nested cycle, was tracked three ways in the 30 interviews with frequencies as a code (34) and as a memo (15). According to Aghion and Howitt (1992, 1997), Nolan and Croson (1995), Schumpeter (1942), and Sombart (1913), creative destruction is a process of transformation combined with revolutionary innovation that occurs at an inflection point. For example, an organization encounters an adversity such as an economic recession, market shifts, or regulatory changes. The organization reevaluates its position, releases forms, processes, and/or norms that no longer serve the organization’s goals and objectives, and develops solutions that not only maintain the organization’s function toward meeting its goals but exceeds expectations. As such, creative destruction is often a precursor to innovation.

The following quotes express the some of the impressions of CUSD2009 Team’s members about creative destruction and their colleagues’ innovations:

I was awestruck. In terms of IA1 and DEA1 building the bed. I think IA1 built the shelves in the kitchen. They made huge revisions to the bed and house just looked like I wanted to live in it. That’s how great it was, to know that we did it ourselves was the best accomplishment of all.

The following exchanges state the events leading to the redesign of the kitchen, which originally specified an integrated kitchen unit by an Italian manufacturer, Boffi, and referred to as “the Boffi” in most interviews. One team member stated the following about development of the kitchen module:

We had gone into negotiations with them (Boffi) and the entire kitchen was centered around this kitchen island. It was really the concept of the entire kitchen to have this island with a slide out since the beginning. We really tried to get it from them but they didn’t budge. And so IA3 who was an architecture student basically said I’ll take that on and that was going to be his project.

Another team member stated the following about the kitchen module:

The kitchen island was fabricated by student when we were originally going to outsource that to a company that would make the island for us. So, we took that in and it essentially eliminated everything but materials costs. That was essentially a complete redesign.

When a faculty member was asked about the kitchen unit by Boffi, the response was, “They weren’t willing to provide that, so it became fabricated by student. I think that this was clearly an

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

issue where the students had to come to terms with the budget.” The following team member’s statement describes the impact of the budget constraint on the kitchen design:

That was probably one of the best things that happened to the house, going back to our student labor that we touched on. IA3 built that for us. That was the piece that Boffi was manufacturing and would have provided for us. It was basically the same concept, but, you know, it was a generic piece and it would have been generic as an island. I mean, having that, “We can’t afford \$10,000 for a kitchen island, so what are we going to do?” I give all the credit to PL1 for this one. He went out and found IA3, who was a great craftsman and he’s going to be a great architect, and PL1 asked, “Can you design this kitchen island for the house?” And, I think, the kitchen island really was central and was so well received and it fit so well into the house. It really made the kitchen. And because of that, the whole kitchen module really evolved and took shape.

The kitchen design emerged as an innovation because it exceeded expectations in light of the budget constraints. One team member’s recollection described how the innovation emerged in detail. The following statement expresses the differences between the original design, using the Boffi integrated kitchen unit and the redesign:

So, the Boffi itself is a beautiful kind of thing, but it didn’t have the right amenities. It wasn’t right for the project—amenities wise. What it had didn’t fit what the house would need. So, the Boffi is an example of something that contains a lot of things but it doesn’t contain everything that you need to have in a kitchen. No matter what they would like you to say, it didn’t. I think there were three different sizes of the Boffi, but I don’t think they had a refrigerator in there. It might have had a microwave or something. So, it wasn’t a full kitchen. So, when I came in, I was shown these plans of the house that had the Boffi in there and the square plan with the table extending and opening up into a stove underneath. So, that was sort of a place to start.

This statement indicates that the original design would not have met the needs of the project and that the redesign exceeded those needs in terms of function and aesthetics. The redesign was innovative because exceeded expectations in unexpected ways. The student team members might not have recognized their own innovation; however, faculty advisors did. It was apparent that the extent of the innovation was demonstrated in energy efficiency, functionality, and aesthetics.

While the results of coding and memo writing indicated that creative destruction was observed in CUSD2009, the terms of the definition of innovation impact how these results can be interpreted. The numeric results indicate that CUSD2009 demonstrated patterns of creative destruction and innovation in coding frequency. From a qualitative perspective, CUSD2009 operated in a context of innovation, in that creativity and talent are encouraged to emerge. Taken as a whole, the numeric frequency and the qualitative interpretation of the data indicate that CUSD2009 Team’s conscious decisions to take adaptive action resulted in creative destruction leading to innovation.

Discussion, Conclusions, and Implications

In this section, the results of the multi-level analysis of the three research questions and their meaning to organizations that rely on project teams for successful projects and innovation are discussed. An integrated systems perspective of the study's results is explained. Conclusions, contributions, implications, and recommendations for future application of complex adaptive systems theory to group development are presented.

Discussion: Integrated Systems Perspective

In this discussion section, the model of group development (Tuckman & Jensen, 1977) and the model of complex adaptive cycles (Gunderson & Holling, 2002) are integrated using four principles of complex adaptive systems theory, specifically self-organization (Ashby, 1962), hierarchy (Ahl & Allen, 1996), emergence (Ashby, 1962; Mintzberg & Westley, 1992; Wheatley, 1994), and learning (Argyris, 1999). The integration of the two models and the theory was a natural step in development of a foundation for the synthesis of the results of this research study. This integrated view is the outcome of the fourth level of analysis.

As demonstrated in Data Presentation, the processes of the adaptive cycle and the principles of complex adaptive systems theory appeared during the phases of CUSD2009's group development. The following integrated systems perspective is my interpretation and discussion of the results. Each subsection introduces an integrated systems view as one of four summary statements about a group developmental phase and its associated adaptive processes in project teams. The four summary statements are:

1. Exploitation is a process of self-organization during forming and storming.
2. Conservation is a process of building hierarchy during norming.
3. Release is a process of emergence during performing.
4. Reorganization uses processes of learning as an outcome of adjourning.

These integrated statements are proposed ways to view the results from a systemic viewpoint; however, this perspective is my preliminary mental model and further research in different settings will likely modify them. This section is presented progressively, including inflection points that are important to team cohesion, group development, adaptation, and project success. Through this synthesis the strengths of each model are highlighted and some of the weaknesses may be diminished. For example, the myopia of the group development model's focus on internal processes is balanced by the external reliance on environmental feedback of the adaptive cycle model.

Exploitation: Self-organization during forming and storming. Forming and storming are group development processes in complex adaptive social systems to self-organize by exploiting material and human resources through selection. As a summary statement, exploitation is a process of self-organization during forming and storming. During this period, the project team's vision, mission, goals, objectives, and operating principles are determined. Examples of how exploitation facilitates self-organization during forming and storming include

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

CUSD2009's initial meetings to respond to the DOE's RFP. The outcome of this process was that the leadership team decided to take a risk with an innovative project design and to operate as a democratic team. Team members described a shift in priorities from individual to group, which leads to an inflection point.

The inflection point where the team shifts from forming and storming / self-organization / exploitation to norming / hierarchy / conservation is when the team resolves conflicts and individual agendas yield to the group agenda through commitment to the project's goals and structure. The following quote shows the transition: "I saw a team of completely, completely diverse people from all over the school really get together and accomplish something that I think was greater than the sum of all of its parts."

Another team member stated the following about relinquishing one's individual agenda for the team's goals in terms of attitude, "In the end, they won't say how hard the work was that they did. If it wasn't for them, and combining with everyone else's forces together, we wouldn't have had the product that we did."

CUSD2009 used exploitation to recruit, select, and match talents to goals in its formation, while exploiting ideas through agreement/disagreement in storming. Early in its development, CUSD2009's focus was on researching designs and resources that would be used for the project. The processes of exploitation were used in self-organization of the team during its formation.

Conservation: Hierarchy building during norming. Norming is a group development process that creates hierarchy by conserving material and human resources through behavioral norms that guide decision making, information sharing, and resource management. Conservation concerns saving time, energy, and resources. The project team's norms are explicitly documented in policies, procedures, and processes or implicitly through tacit agreements about acceptable and unacceptable behaviors. As a summary statement, conservation is a process of building hierarchy during in norming. Examples of explicit norms are CUSD2009's artifacts including a project manual, budgets, value engineering spreadsheets, PowerPoint presentations, and a tour guide training manual. An example of implicit norms and assumptions is described in the following quote: "You know, it was told to me directly by FA1 and FA2, so, I'm not quite clear on who it came from. I just never questioned it. I just said OK, 'No deficit spending.'"

CUSD2009 had decided on a democratic structure during the forming and storming process. During the norming process the team continued to organize using a democratic (horizontal hierarchy) structure through peer norming, as opposed to autocratic, power norming (vertical hierarchy). While the interpersonal dynamics of the democratic structure were developing, the operational dynamics were also being determined. The team used cost estimates to track expenses for materials and services. Policies for conservation were implemented through the hierarchy of the leadership board and subteam leaders of CUSD2009. The policies were based in norms about balancing design ideals with budget constraints.

Conservation was evident in two distinct ways. First, conservation saved team energy and effort through conformance to behavioral norms. Second, conservation was achieved through specific tracking procedures (Cornell web financials) for purchasing supplies executed through the team's infrastructure, which added accountability, saved time, and saved money. In addition

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

to cutting costs for material resources, CUSD2009 cut the project's labor costs by shifting from contracted labor to student labor as much as possible. Volunteering for manual labor became an acceptable behavior and norm by team members when it had not been expected in earlier plans for the project.

The inflection point when the team shifts from norming/ hierarchy/ conservation to performing/ emergence/ release is when the team develops cohesion through conformity to group norms. Norm negotiation and team cohesion are important for effective decision making. If there is too much conformity in group norms (positive groupthink) or too much time is spent reaching consensus, decision making is ineffective (Postmes, Spears & Cihangir, 2001). The team coalesced through hierarchy building to conserve resources during norming, which helped integrate individuals into the team with greater ease than at earlier points in the development of the team. As an interviewee remarked,

It's interesting because it's always a challenge to bring new members in and get them inculcated into a group and have them feel a part of it. So, the intensity of that experience - the very, very hard work, plus the need for collaboration, and being pushed or stretching yourself - is somewhat necessary.

Once the team had coalesced and its infrastructure was in place, it was well positioned to apply its resources toward achievement of the project's goals. The processes of conservation as hierarchical decision making resulted in actions and reinforced the renegotiated norms to support the team's progress.

Release: Emergence during performing. Performing is a group development process in complex adaptive social systems for the emergence of progress toward achievement of goals through the release of tightly bound material and human resources. As a summary statement, release is a process of emergence during performing. It marks a shift from team organizing to team production. The decision in April 2009 to commence construction of CUSD2009's Silo House signaled the release of financial, material, and human resources. Release continued through construction during the summer of 2009, as team members provided labor and the university provided financial resources.

Emergence as release of pent-up energies was expressed during the construction period (performing) in different forms, such as creative partnerships, collaboration, and leadership. The counterweight bed that rose into the ceiling to free space in the bedroom for other uses is an example of creative partnerships. Another example of emergence was the creation of a website through collaboration that won second place. While it was apparent that leadership emerged at the team leader and board level, leadership and teamwork emerged throughout the entire team in the subteams.

By the end of the summer 2009, construction had been substantially completed. While a tangible emergence of the team's performance was evident in the Silo House, additional CUSD2009 development emerged as other students joined the team as tour guides. The culmination of CUSD2009's vision, mission and goals were achieved by its participation in the New York State Fair in Syracuse in August 2009 and the DOE's Solar Decathlon on the National Mall in Washington, DC, in October 2009.

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

The inflection point where the team shifts from performing/emergence/ release to adjourning/learning/reorganization is when the team reflects and evaluates the project in terms of goal performance and team development. The following quotes summarize the reflections of some of the team members. One team member said, “With the design, we over designed it and we under budgeted.” Another team member stated, “I think one of the good things about a team is that everyone feels the pain of failure together, but everyone also feels the success together.” If the team debriefs about what went well, what did not go well, what could be improved, and effective use of feedback, the team has a foundation for learning from the project experience that can be applied in reorganization and other projects. If not, the potential for development of resilience and adaptive capacity are lost. The consequences of not formally debriefing the team include repetition of errors and failures. At this point, the project team has enormous potential to learn through reflection upon what emerged through the release of resources during performing. I believe this is a key leverage point for building adaptive capacity and transformative change that project teams can contribute to organizations. In my experience, it has been often overlooked and dismissed when it could be effectively captured and applied in future projects during reorganization.

Reorganization: Learning during adjourning. Adjourning is a group development process in complex adaptive social systems that can support the reorganization of project teams toward new goals through learning from experience and applying lessons learned. As a summary statement, reorganization uses processes of learning as an outcome of adjourning.

It is important to note that Tuckman and Jensen’s (1977) model did not fully develop what exactly needs to happen during the adjourning phase of group development. Their lack of explication presents an opportunity to do so. I suggest that formal team debriefing enables team members to reflect on their team’s experience and to formulate applications for the lessons they have learned. By doing so, the team invokes the second loop in double-loop learning (Argyris & Schön, 1978). In addition, adjourning presents an opportunity to review feedback the team received and to incorporate it into the team’s reorganization. Learning to rapidly respond to environmental feedback builds resilience, as demonstrated by HROs (Burke, Wilson & Salas,, 2005).

CUSD2009 adjourned rapidly in October, after the conclusion of the DOE’s Solar Decathlon on the National Mall in Washington, DC. The project team leader, PL1 attempted to conduct team debriefings. Team members who wanted to reorganize CUSD to focus on solar design have done an assessment and evaluation of the CUSD2009 project in support of their new project goals. Team members expressed a wide variety of reflections about their team experience. Their reflections ranged from what went well, what did not work well, what could have been done differently, and what needs to be addressed in future projects like this one. One of the team members reflected, “That’s why I would love to work together with them again because, we can come up with something that would truly change the way people think about architecture and the way they think about green building.”

The value of the CUSD2009 experience in the reorganization of the team into CUSD emphasizing sustainable design in future projects was summed up by one of its new leaders,

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

“It’s unparalleled, which is why we feel so strongly about keeping it going and why... but our primary mission statement for the team is that it is going to be first, and foremost, about our education, and our learning experience.”

The inflection point of application is when the team shifts from adjourning/ learning/ reorganization to a renewed cycle of forming and storming/ self-organization/ exploitation applying the lessons learned during the prior project experience to the reorganized team’s goals. If not, the potential for development of resilience, adaptive capacity, and organizational learning are lost. The following statement indicated the shift to a renewed adaptive cycle from the CUSD2007 project to the 2009 project and the value of the experience, “I admired a lot of people on the 2007 house and I admired that they were trying to do. I was definitely excited to have an opportunity to put in my own input about how I would have done things differently, I suppose.

This team member related, “It’s an opportunity that you can only have if you start from the beginning and see it through the whole two years.” Other team members expressed how CUSD2009 would impact their plans in their careers and how they would use the lessons they learned in other projects.

These reflections indicate that the lessons learned during CUSD2009 may be applied in a future generation of the CUSD or in other projects. From this data, the importance of reflection, evaluation, and application of lessons learned during a project are emphasized. As a result, it is critical to make time for project team debriefing during adjourning for the purposes of learning and applying insights gained during the project so it can be used in reorganization at the team and organizational level.

Integrated systems perspective summary. The integration of the data results using the group development model (Tuckman & Jensen, 1977) with the complex adaptive systems model (Gunderson & Holling, 2002) through complex adaptive systems theory yielded several insights. As a project team, CUSD2009 demonstrated that exploitation is a process of self-organization during forming and storming. It found that conservation is a process of developing hierarchy during norming. CUSD2009 showed that release is a process of emergence during performing. CUSD2009’s reorganization used processes of learning found during adjourning when debriefing occurred with reflection, integration, and application to new projects.

As a synthesis of the fourth level of analysis, the integrated systems perspective of CUSD2009 shows that the two models and the theory overlap and interrelate while not necessarily having distinct and clearly delineated correspondence. This was expected, as social systems are fluid. The ecological model of adaptation relies on time and space scales. Meanwhile, the group development model also includes human agency in terms of meaning/ sense making. It may be expected that adaptation would be a set of behaviors within group development and not a direct correlation. Unlike ecological reactivity to environmental change, humans need to make sense of change and develop a response to it. As a result, the need of humans to make sense of change impacts how they change.

Conclusions

Research questions. The results for the first research question revealed the role of conscious awareness of the need to change and adapt, which brought a sense of urgency for most of the leadership and many of the members CUSD2009. The project team had expected phases of group development to the point when the adversity became known. It had spent over 14 months focusing on internal processes. With the identification of a \$60,000 financial gap, the environmental constraints of the project were recognized. The team's leadership was careful in how it communicated this information to subteam leaders and general team members, taking care to emphasize exigency, while managing the risk of mass exodus and panic. The framing of this critical information impacted how the team responded to the crisis.

The results for the second research question had significant implications for CUSD2009, as the team decided to assess its situation, evaluate its options and alternatives, and continue to pursue its original goals by adapting its processes. The project team decided to adapt its function in order to meet its goals. CUSD2009 demonstrated numerous examples of actions taken to adapt including cost cutting measures and fundraising campaigns. The adaptation followed the pattern of complex adaptive cycles at a whole team level and at a subteam level. Substantially, the adaptation entailed renegotiation of group norms at multiple levels (e.g., budget reporting, design decisions, student labor).

The results for the third research question concern an inflection point and its corresponding nested cycles, specifically creative destruction and how it manifests in project teams. In the results from the second question about actions taken to adapt, the team had responded at two levels. The entire team adapted its processes and subteams adapted their processes. In addition, the results of research question three indicate that two forms of nested adaptive cycles occurred.

Contribution and Implications

The reason this study focuses on project teams is that I believe, project teams are an untapped resource for adaptive learning in organizations. They are a leverage point for transformative organizational change. As a project manager, I have had a "foot" in two worlds that typically do not interact well in organizations—technical and organizational professionals. I have found that successful projects require a liaison, someone with competence in both fields who could synthesize needs and speak the language of both areas of expertise. This research confirmed the development of project managers is a potential leverage point for transformative change in organizations seeking leadership and organizational resilience. Project managers may benefit from leadership coaching.

The significance of this study is its systemic perspective of group development that can be presented and discussed with technical project managers using their language. This study crosses disciplinary boundaries to introduce humanistic values of organizational systems into task and object-oriented organizations using concepts, models, and metaphors that technical professionals can identify with and understand. While the results may be interpreted and debated, a dialogue may be started and greater understanding gained. I believe this is a critical point where embracing change can be cultivated in organizations.

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

A potential contribution of this study was an understanding of how the inflection point and the nested cycle of creative destruction works in project teams. It revealed the nature of resilience in project teams, as well as the beliefs, assumptions, values, and norms that are inherent in resilient organizational cultures (e.g., degree of versatility or flexibility, a belief that negative feedback is an opportunity for improvement not failure). Further, it suggested that institutionalization of competencies that support the renegotiation process (flexibility, versatility, and adaptive capacity) as important in developing a resilient organizational culture.

Fundamentally, this research study's contribution to the fields of organizational behavior, organization development, and organizational systems is its perspective of group development through the lens of complex adaptive systems and project management. The comparison of the group development model with the panarchy model through complex adaptive systems theory highlighted the internal process focus of the former and the external focus of the latter. While there were similarities, the differences yielded insights into aspects of adaptation human systems can learn from ecological systems. Specifically, two of the lessons for project teams are: (a) to develop environmental awareness of constraints as well as opportunities, and (b) to use feedback to anticipate adversity and plan for it. Both of these lessons require project team to look beyond their internal developmental focus. From an organizational point of view, project teams can facilitate transformative change and this opportunity can be leveraged by formalizing the adjourning/reorganization process using debriefing and selecting leaders based on the leadership behaviors. This study found that adaptive capacity is built from both the top down and bottom up. Organizational resilience requires project team adaptation and innovation, as well as adaptive leadership.

The implications of this research study span across a wide range of topics in organizational systems including group development and social systems science. This research study observed a case of CUSD2009's project team experience through an approach of comparing and contrasting between organizational behavior and ecological adaptation. I used a model from each discipline which was considered to be widely held and validated through research and application. Another researcher may choose other models and, as a result, reveal nuances that were not addressed in my research design. That realization implies that far more research is needed in this area using complex adaptive systems theory as an overall approach to the research design.

The emergent categories of organizational culture, inflection points, nested adaptive cycles, leadership, and innovation are salient themes in organizational systems that merit further investigation. The emergence of these categories in this study indicates that they are important factors in group development, especially in developing resilient project teams. While this study was not designed to address them with sufficient definition and rigor, future studies could easily address each category separately to provide deeper insight into their impact adaptation in organizational systems.

From a larger perspective, this research contributes to our understanding of how groups can adapt to change and adversity with less uncertainty and greater confidence. This study allowed me to translate its results into language that may be more easily understood and readily adopted by technical project teams. Understanding how to be resilient in an environment of swift, global change is a critical competency for groups. It is my hope that this research deepened

our understanding so, as American anthropologist, Margaret Mead said, “Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it is the only thing that ever has.”

Recommendations

A significant portion of this study set the foundation for the three research questions by verifying the relationship between group development and complex adaptive cycles using complex adaptive systems theory. I recommend that future research focus on any of the identified integrated processes of adaptation, on inflection points, on nested adaptive cycles, or on other phenomenon such as the emergence of leadership, the emergence of innovation, and the mediation of organizational culture in complex adaptive social systems. Researchers may choose to use different group development models or adaptive models. Researchers may also choose to focus on the dynamics of one of the principles of complex adaptive systems or choose other principles and then explore these processes in greater depth than provided in this study. In addition, researchers may decide that the cognitive framework should be grounded in group construct theory (Kelly, 1963) using repertory grid method. Any of these research approaches would contribute to the body of knowledge and further the dialogue by applying complex adaptive systems theory to group development.

This study revealed the difference between group development and ecological adaptation by identifying the focus of each model as predominately internal versus external, respectively. In ecological adaptation, the system reacts to its environment to survive or it perishes. In human adaptation, humans need to understand their environment to choose a response. The role of environmental feedback and how it is used is essential to adaptation in both systems.

For those interested in understanding organizational and social systems from a complex adaptive systems perspective, it is important to understand that human adaptation, unlike ecological adaptation, is mediated by the drive for meaning / sense making (Weick, 1995). Vickers (1968) considered the drive for meaning to be characteristic of an “appreciative system.” Human agency, which is a form of meaning / sense making, mitigates adaptation. Agency can increase uncertainty by its inherent unpredictability. Viewing complex adaptive social systems as appreciative systems may inform this research further in future studies.

For organizational systems practitioners, anticipating a need for adaptation puts project teams in a better position to use feedback and prepare for adversity by reducing uncertainty. Using feedback to prepare for future challenges builds adaptive capacity within the team and potentially in the organization when team members disperse and join other teams, applying their adaptive experience. Conscious awareness and adaptive action allow teams to respond rather than to passively react. Simply put, practitioners need to incorporate feedback and reflection into learning practices in organizations by making project team debriefing a part of the adjourning and reorganization processes. The role of feedback in project teams has been studied in HROs. Wilson, Burke, Priest & Salas (2005) explicated how feedback may be effectively used in project teams. Practitioners may find their work especially useful when modified for their operational contexts. Practitioners may also want to examine the role of leadership and organizational culture in project management with respect to anticipating adaptation and preparing project teams for change.

A CAS VIEW OF RESILIENCE IN A PROJECT TEAM

Finally, whether scholar, practitioner, or project manager, it is important to recognize one's impact on the complex adaptive social system within which one lives and operates. Often we deny our roles and impacts on events. This was made clear to me at a recent conference. Several of the conference attendees were involved in ecological and environmental interventions. They were scholarly experts about complex adaptive systems, yet they failed to recognize themselves as part of the systems in which they were intervening, preferring to view themselves as objective observers. In action research (Lewin, 1947a, 1947b) the principle that the observer impacts the observed is vital in the interpretation of results and the development of recommendations for further interventions. For those who perform research, implement practices or interventions, or are interested in complex adaptive systems, the principles of adaptive management as explicated in Westley's essay (Gunderson & Holling, 2002) are useful guidelines to apply in your approach to projects.

Closing Reflections

As I reflect on the research and the CUSD2009 Team's experience, I have a greater appreciation of how embracing change impacts adaptive group development and the potential for the emergence of innovation through creative destruction. Vickers (1972) was a proponent of "rocking the boat," which the CUSD2009 did by choosing a solar house design that went against the grain by using cylinders instead of boxes. He would have considered CUSD2009 an *appreciative system* (Vickers, 1983).

The study's results emphasized the importance of a project team's consciousness of its environment and the criticality of scanning for feedback throughout the team's group development for adaptive opportunities. There remains much more to learn, especially about how the development of project team resilience may scale up to organizational resilience. It is just a beginning of the use of complex adaptive systems theory to understand group development in project teams and organizational systems.

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