Biomimetic Leadership: From Theory to Practice

Andrea Somoza-Norton
California Polytechnic State University

Shawna Whitfield
California Polytechnic State University

Abstract

Biomimetic leadership is a pioneering framework viewed through the ecological lens, in which every living system reveals practical applications and sustainable solutions to systemic challenges. Extended office hours and stressful environments have distanced administrators from nature-inspired activities and practices. This mixed methods study explored the impact that teaching biomimetic leadership principles has on educational leadership graduate students. The results indicate an increase in awareness of nature's Life Principles: adapting to changing conditions, integrating development with growth, and being locally attuned and responsive. We found that simply being introduced to biomimetics led to inspiration for aspiring educational leaders.

Keywords: biomimetic, education, leadership, nature, strategies

Biomimetic Leadership: From Theory to Practice

This research project aimed to promote awareness of nature's value through biomimetic thinking, supplement participants' leadership skills, and impress the significance of sustainability upon participants. Specifically, the study's rationale was to determine any differences in students' knowledge and applications of biomimetic leadership principles from pre- to post-test. Second, the data collected and analyzed from this project serve to refine professional development planning for educational leaders and to contribute to the emerging study of biomimetic leadership. The following literature review provides the reader with a theoretical background.

Literature Review

Leaders, in any context, are actors who operate in complex organizational ecosystems (Bolman & Deal, 2013). Indeed, organizations share many elements of ecological systems including self-organization, advancement, and networking. As in nature, organizations' rules and policies can generate intricate behavioral patterns, and system dynamics leading to deterministic chaos, "a phenomenological behavior of chaos—i.e., sensitivity to the tiniest changes in initial conditions or seemingly random and unpredictable behavior that nevertheless follows precise rules" (Solé & Bascompte, 2006; Bishop, 2017). Organizations are active communities; as such, individuals' efforts, interactions, and teamwork undoubtedly mirror phenomena encountered in nature. Recognizing the parallel that exists between organizational and biological ecosystems would benefit 21st century leaders and managers.

The field of biomimicry, also known as biomimetics, has encouraged a view of learning from the lens of nature, a strategy that enables us to live more resourcefully (Benyus, 1997). Inventions like solar panels, Velcro, and corrugated paper are among the many designs inspired by nature. Biomimicry is "an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies" (Biomimicry Institute, 2018). Likewise, *biomimetic leadership* refers to the ability to lead effectively by applying nature's proven strategies to initiate growth, optimal interconnection, interdependency, and positive outcomes in an organization. Its conceptual foundation lies at the intersection of various disciplines such as: *a) nature's six Life Principles, b) biomimicry thinking elements for social innovation (Ethos, Emulate, rEconnect), c) sociobiology, d) systems thinking, e) professional standards for educational leadership and f) contemporary leadership theories* (Figure 1).
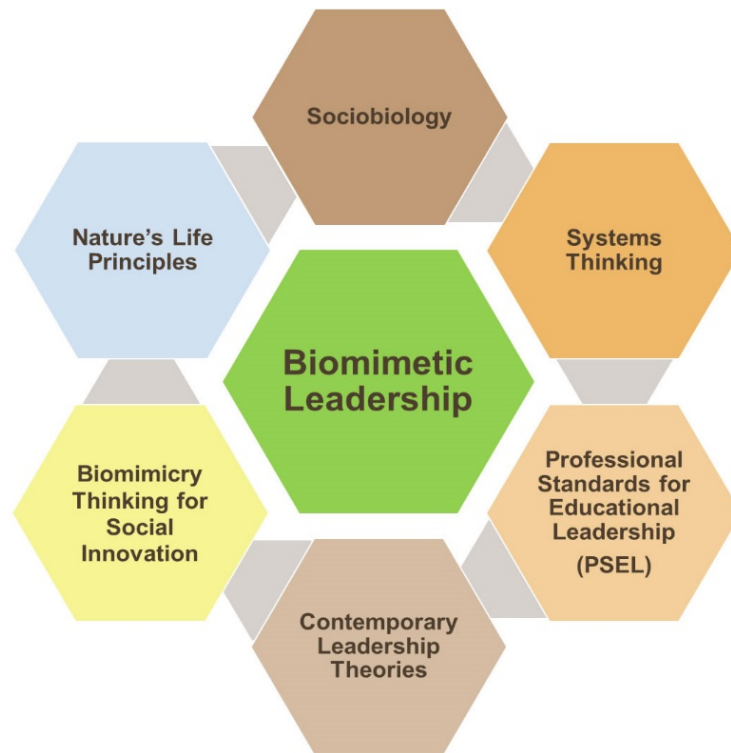
Figure 1. Biomimetic leadership conceptual framework

Nature's Life Principles (Biomimicry Institute, 2018) are designs nature offers to humankind. The principles are an invaluable combination of approaches and patterns found among the species living and flourishing on our planet. In studying these well-researched strategies, nature becomes a mentor and can assist leaders in optimizing the lives of their organizations. For instance, the principle *adapt to changing conditions* has been explored in the area of change leadership and management for decades. Nevertheless, except for a few authors (Hutchins, 2013; Tazzi, 2016; Woolley-Barker, 2017), the literature is mostly silent on the application of biological examples to leadership. The principle of *evolve to survive* points to replicating strategies that have worked in the past: learning from the unexpected to inspire new ideas and vigilance about new information in order to reorganize and generate options. In nature, the results of reshuffling information can be seen in the genetic modification of offspring, which may improve chances for survival. A human example of this method is when employees change jobs and cross-pollinate information across organizations (Baumeister, 2014).

The principle *integrate development with growth* suggests approaches for maintaining stability and prevailing under complex circumstances. With self-organization, an element of this principle, we observe birds, ants, fish, and many other species employ graceful and uncomplicated survival techniques. For example, "[f]locks of birds dance across the sky, as if following choreography. Without a director, these birds self-organize with simple rules that effectively result in emergent, aligned community" (Biomimicry for Social Innovation, 2018). These examples can generate rich discussion on alignment and self-organization.

In the midst of our daily routines, it is easy to withdraw and forget to be in sync with our natural surroundings. To *be locally attuned and responsive* addresses the value of clear communication and unobstructed feedback loops that nurture cooperative relationships and

focus on local supplies and energy. In the case of feedback loops, nature offers plentiful representations. White clover, for example, "use feedback loops to fend off herbivores. When eaten by a caterpillar, they chemically adjust their leaves so they are harder to chew, which the caterpillar interprets as a signal to feast elsewhere" (Biomimicry for Social Innovation, 2018).

As society demands more ecologically responsive leaders, the principle of *be resource efficient* serves as a standard for the competent and sensible use of limited resources and opportunities within an organization, i.e., sustainable practices, managing a team's time and using low energy processes in long-term projects.

The last principle, *use of life-friendly chemistry,* reminds us to streamline processes and break products down into non-threatening components, innovate, and make use of a small and selective subset of elements in projects. Figuratively speaking, this notion can inform those in charge of intricate ventures of the advantages of breaking apart processes whenever possible. Each of these principles and their descriptors presents exceptional opportunities for applications in leadership and management.

Biomimetic leadership does not purely search for leadership models in nature, it also seeks to understand how certain species collaborate as communities to achieve goals. Sociobiology is "the systematic study of the biological basis of all forms of social behavior, in all kinds of organisms, including man" (Wilson, 1978, p. 16). Sociobiology's examination of various species' modes of organization, principal forms of communication, and division of labor informs biomimetic leadership. Sociobiology aims to predict a species' social organization by examining its unique population factors combined with information on its behavioral limitations (Wilson, 2000). From an evolutionary perspective, leadership is associated with species' leader-follower patterns and not necessarily with a leader's traits and attributes. Wilson clarifies that "[w]hen zoologists speak of leadership, they usually mean the simple act of leading other group members during movement from one place to another" (p. 311). However, the question among those examining these actions is how members reach an agreement to relocate as a collective. According to Vugt (2006), "Usually, this can be solved if one individual takes the initiative, and the rest acquiesce and follow. Leader-follower patterns may have emerged in many social species to solve coordination problems such as these" (p. 256).

Honeybees, for example, have shown remarkable leadership signals beyond what we see in any other non-human vertebrates. In *The Smart Swarm: How Understanding Flocks, Schools, and Colonies Can Make Us Better at Communicating, Decision Making, and Getting Things Done,* Miller (2010) describes the insects' indirect collaboration, self-organization, and networking. The well-known hive waggle dance and buzzing are autocatalytic reactions to get bee workers airborne. Similarly, the preflight actions of flocking Canadian geese also reveal behaviors that trigger the rest of the group to fly (Wilson, 2000). In the same manner, individual termites respond to environmental variations that exemplify a biological collaborative behavior. If a termite worker carrying a grain of soil, for example, comes across a small pile of dirt left by fellow workers, it will drop its grain on the pile. That action, in turn, stimulates other workers to do the same and soon, if there are enough termites, the small pile of dirt grows into sizable pillars. Termites and other insects, such as ants, have ingenious communication structures that allow them to efficiently collaborate regardless of the size of their colony (Bogatyreva & Shillerov, 2015). Human leaders can learn valuable lessons from these mound-building termites. For example, it only takes one motivated employee to spark a collaborative trend in an institution. This action is called *stigmergy* and it is ubiquitous in

superorganism societies (Woolley-Barker, 2017). We see stigmergy when humans contribute to a wiki; an initial post triggers the rest of the users to contribute to the site.

Biomimetic leadership is also fundamentally coupled with systems thinking, as there are boundless systems archetypes present in nature (i.e.; isolation and relationships, and reinforcing, balancing, and feedback loops). The systems thinking model has been influential in the field of organizational learning since the latter part of the 20th century. Experts in systems thinking and dynamic models, such as Capra (2014), Senge (2014), Forrester (1980, 2009), Ackoff (2005), and Deming (2000) have promoted its principles for decades. Nature is a colossal system that can test assumptions, identify leverage points as needed, and transform its elements in order to survive. The forms and functions of organizations mirror living systems. As such, they are always adapting, generating pockets of energy, self-organizing by the system's own internal rules, and crafting new order in times of uncertainty. Systems thinking allows individuals to distinguish how systems interact and make meaningful connections, but most importantly, it supplies the lens to "see the forest for the trees,"—in other words, to see the big picture:

> Systems thinking utilizes habits, tools, and concepts to develop an understanding of the interdependent structures of dynamic systems. When individuals have a better understanding of systems, they are better able to identify the leverage points that lead to desired outcomes. (The Waters Foundation, 2017)

Systems thinking has been introduced in education with some success. Benson and Marlin's (2017) fourteen habit-forming activities book on becoming a systems thinker is an example of the efforts to educate teachers and students on the value of systems thinking. The book's exercises include information about how a system's structure generates its behavior, how elements of the system change over time and generate patterns and trends, and information about feedback loops and delays in the system. Application of systems thinking and understanding the relationships that make up an organization is a cardinal skill for leaders. As a result, this theory aptly complements biomimetic leadership.

The Professional Standards for Educational Leadership (PSEL) (NPBEA, 2018) and four contemporary leadership theories (Adaptive, Situational, Transformational, and Servant), present unique elements in common with nature's designs. Each of the ten PSEL interdependent standards and key indicators outline the expectations educational leaders must meet to initiate and sustain student success. For instance, one Life's Principle, *integrate development and growth*, and *ethos* (essential element) can inspire and give ideas to leaders to better implement PSEL 1: Mission, Vision and Core Values. PSEL Standard 10: School Improvement, specifies, "employ situationally-appropriate strategies for improvement, including transformational and incremental, adaptive approaches and attention to different phases of implementation" (NPBEA, 2018). The Life's Principles can supply leaders with models to create a cyclic information flow in their institutions which can assist managing stakeholders' reactions appropriately in times of change. Appendix A illustrates the viable intersection of the Life's Principles and its related design and strategies (i.e., using feedback loops, building from bottom up, incorporate diversity) and the three essential elements of biomimicry thinking (*Ethos, rEconnect and Emulate*) with PSEL.

Adaptive leadership hinges on the theory that technical solutions cannot solve people problems (Glover et al., 2002). Instead, systems are adapted to accommodate the unexpected without a single leader controlling an expected outcome. Within the organization is intentional redundancy, a willingness to work with opponents, and encouragement to celebrate and incorporate diversity. This dynamic environment is made safe through deliberate transparency, integrity, and a safe space to reshuffle information. The theory of

adaptive leadership fittingly exemplifies four of Life's Principles: *adapt to changing conditions, be locally attuned and responsive, use life-friendly chemistry,* and *evolve to survive.*

A situational leader possesses the tendency to adapt to the changing conditions of a specific environment by also incorporating the fundamental principles of *being locally attuned and responsive* and especially making it a priority to *be resource efficient*. Also, a situational leader is aware that power should be given to followers, who in turn determine the power of the leader (Hersey, 1988).

A third theory, transformational leadership, is characterized by growing and elevating the goals of followers (Bass, 1997). As with situational leadership, transformational leadership exemplifies the principle of *evolve to survive*, due to the fact that the decentralization of power centers around providing motivation that extends to followers beyond their own self-interests. Transformational leadership also reflects three other principles: *be locally attuned and responsive, integrate development with growth,* and perhaps most importantly, *adapt to changing conditions,* as the leader must act, be transformative, and respond to dynamic contexts.

Finally, servant leadership embodies relational integrity and respect throughout all levels of an organization. The object of servant leaders is to integrate development with growth. They also incorporate the principles of *adapt to changing conditions* and *be locally attuned and responsive*. Followers of devoted servant leaders are inspired to become servant leaders themselves (Newman et al., 2015). In this model, strong service-based relationships must be accompanied with a focus on intentionality and efficiency. Similarly, Life's Principles intertwine to generate a state of mind that produces conditions conducive to a sustainable and healthy organization. Just as earth's geosphere continually filters, layers, recycles, and incorporates all matter, so may Life's Principles be flexibly applied to these contemporary leadership theories.

Methodology

The purpose of this study was to examine and better understand the effects of introducing biomimetic leadership principles to educational leadership and administration students. Specifically, we were curious to know whether there was a significant change in student awareness of biomimetic leadership principles after the instructional activities were implemented.

Setting: Leadership Synthesis Course. The data were collected in a five-week, intensive summer leadership synthesis graduate level course. The instructional activities included a seminar on the conceptual and operational frameworks of biomimetic leadership, group sharing and reflection, bio-inspired leadership application examples, and a group nature walk in a nearby green path. This four-unit graduate course is required to complete the masters in educational leadership and administration. It is designed to provide integrated experiences and to maximize the application of the roles and responsibilities of school leaders. The teaching methodology incorporated experiential learning, gamification, storytelling, and dialogue (Robinson & Moraes Robinson, 2014). All of these pedagogical approaches aided the students to link theory to practice and have a deeper understanding of the subject.

Population. The convenience sample consisted of working professional students enrolled in a graduate educational leadership program at a state university in California. Two cohorts of 17 and 24 students respectively participated in this study. Participant age ranged from 24-51 years with 96 percent between the ages of 28-51. Thirty out of the 41 students were pursuing the preliminary administrative credential which requires a minimum of 5 years of successful teaching experience. Eighty-five percent of the students were female which is representative of the teaching profession (NCES, 2018). The study was completed during the 2017 summer quarter. The number of required credits taken during this quarter was 12 units. Students' summer quarter grade point averages (GPA) ranged from 3.80 to 4.0, with an average student GPA of 3.90.

Instrument. Because no pre-existing tool was available to measure self-perceptions in this emerging field, an instrument was developed based on the Life's Principles. The survey questions were categorized into the three biomimicry essential elements: *Ethos*, *rEconnect* and *Emulate*. The survey contains 28 items, 7-point Likert scale questions ranging from 1 = strongly disagree to 7 = strongly agree. The post-survey includes two open-ended questions. The same inventory was used in the pre- and post-administration. Overall, the full inventory was found to be reliable (28 items; α = .88). In addition, responses were grouped and evaluated by principle. Internal reliability for each principle ranged from .56 and .80. Participants were homogeneous in age, ethnicity and years of professional experience. Therefore, demographics did not influence the biomimetic leadership surveys results.

Procedure. In this study, the fundamental reason for selecting a convergent mixed-methods design was the ability to compare different perspectives from quantitative and qualitative data. The strength of this methodology is that both types of data are collected during one phase of the research at the same time (Creswell & Clark, 2007). The pre-survey was administered immediately before the introductory lesson and outside activities. The post-survey responses were collected just before the end of the summer quarter. The objective of the two open-ended questions in the post-survey (see Appendix B) was to interpret the effects of introducing biomimetic leadership principles on participants' leadership behavior and to ask the participants for feedback on the pedagogical approaches used throughout the experience. First, each data set was analyzed independently and, later, through the procedures of a side-by-side comparison by simultaneously displaying pre- and post-quantitative data. Paired t-tests and Wilcoxon test were used to evaluate any difference between the pre- and post-surveys. The open-ended survey questions were analyzed using WordStat (Provalis, 2018) content analysis software program to determine emerging themes. Supplementary analysis also included descriptive statistics to obtain frequencies, means, and standard deviations of response items.

Results

Quantitative results. Paired t-tests (parametric) were used in this study to observe any differences between the pre- and post-survey scores. The results indicated a moderate increase in mean scores across most of the 28 items. However, items 18 through 21 showed a significant increase (Figure 2). These items (see Appendix B) measured the level of new biomimetic awareness and its impact on participants. The value of t was -3.021. The value of p was 0.005. The result was significant at $p \leq 0.05$. Wilcoxon (non-parametric) test was also performed resulting in a W-value of 39. The critical value of W for N = 28 at $p \leq 0.05$ was

116. Therefore, the result was significant at p≤ 0.05. The Z-value was -3.734. The p-value was 0.0002. The result was also significant at p≤ 0.05. Furthermore, the correlation value for the pre- and post-surveys was R: 0.72 which is a moderate positive correlation.

Descriptive statistics also showed an overall moderate increase in means and a decrease in variance and standard deviation in the post-test (Table 1). The decrease in variance and the standard deviation is an expected output as participants' responses become less reactive after each additional treatment.

Table 1.
Descriptive Statistics Pre- and Post- Survey Scores

	Mean	Variance	Standard Deviation
Pre scores	4.56	2.43	1.56
Post scores	5.19	1.66	1.29

Items such as "I embrace unexpected situations," "I use readily available materials rather than generating/purchasing new ones," "I accomplish big goals by starting with the big picture and top-level decisions," and "I accomplish big goals by building from the bottom up" exhibited a significant increase compared to the rest of the items. The latter statements illustrate the participants' flexibility to assess organizational situations from both ends of the spectrum. Items 18 through 21 showed an increase of 3.19 mean average (Figure 2). These four items dealt explicitly with self-assessing new concepts; i.e., "I am aware how biomimetic leadership can help me with decision-making and problem-solving in organizations" and "I am aware how biomimetic leadership can help with innovation in organizations."
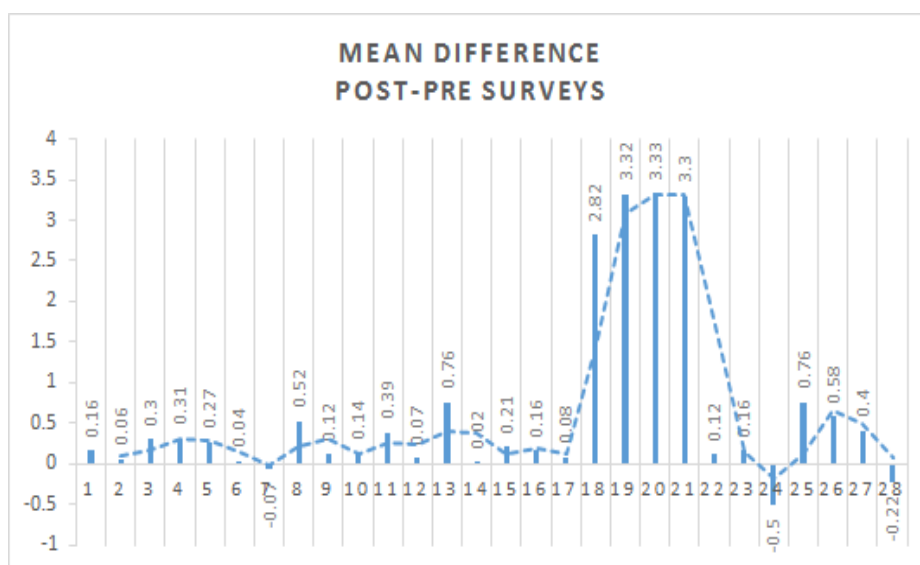

Figure 2. Mean difference pre-post surveys

Finally, six items out of the 28 are considered reverse worded items, and were analyzed by correlating the negatively worded items with their reverse-coded correspondent items, to verify that correlations were in fact r = −1.00. These items were constructed to reduce or prevent any potential acquiescence bias.

Qualitative results. The power of qualitative data is that it provides rich insights and gives an extra dimension to the quantitative data. The post-survey included two open-ended and reflective questions (see Appendix B) which allowed students to share their opinions about the usefulness of biomimetic leadership principles, and ways to improve the delivery of the instructional activities. A content text analysis was conducted using WordStat (Provalis, 2018) software. After inputting the definitions of each category in the text analytics program, displayed themes were extracted, relationships, and trends which may not be apparent when content analysis is executed manually. The program identified the frequency with which specific categories and terms appear in the students' open-ended responses. Four areas, as seen in Figure 3, were detected to have the most effect on student leadership behaviors: *discover nature's value, adapt to changing conditions, be locally attuned and responsive, and evolve to survive.*
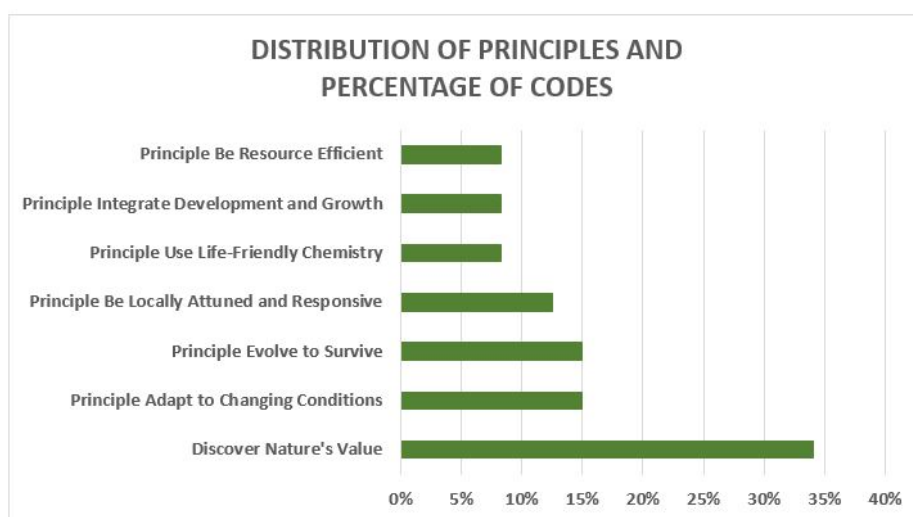

Figure 3. Distribution of principles and percentage of codes

When asked if the instructional activities helped them to acknowledge the role biomimetic leadership could play in organizational leadership, 89 percent of the students responded "Yes." A student further clarified:

> I have always felt that we could learn from nature, one of my favorite examples has always been learning from animal adaptations, like a lizard that loses its tail in an effort to escape capture or the oil on a duck's feathers. I see where we can, in fact, parallel our behaviors and adaptations from nature to be more successful (Participant 20).

The code with the most significant frequency proves to be *discover nature's value.* The narratives within this code revealed that students yearn for outdoor activities, time to ponder outside the constricted environments of their organizations, and are curious about how nature creates conditions conducive to life.

Humans are always learning something new about nature so we will never tire of learning about biology and its application to our lives. Being able to apply these concepts to organizational leadership is thought-provoking and commonsensical (Participant 13).

This behavior indicates the innate attraction all human beings have towards nature or what Wilson (1995) called *biophilia*. Students reiterate that more time was needed outdoors, to deeply analyze and synthesize the concepts learned.

There is also a sense of rediscovery which is linked to the element *rE-connect* of biomimicry thinking, as well as an acknowledgment of the principle *be resource efficient*. Moreover, the term "sustainability," which is "to create and maintain the conditions under which humans and nature can exist in productive harmony to support present and future generations" (U.S. EPA) appeared to be a consistent underlying topic in classroom discussions and narratives. It refers to participants' deep thoughts regarding current global environmental issues and the preservation of limited natural resources, as one articulated:

This biomimetic concept has forged a new lens of understanding, metaphorically and concretely. There are many facets to nature as well as leadership, and I agree that all systems should be engineered with sustainability in mind. Nothing (resources, energy, organisms) is wasted in nature, and that is an important concept to extend to all aspects of life (Participant 14).

Another student commented that the topic of biomimetic leadership brought a renewed awareness to search for answers outside of our typical surroundings: "It reminded me to use the world around me to look for answers" (Participant 34). One aspect repeatedly mentioned was the notion of using biomimetic examples as a metaphor to engage others in organizational and policy change. Students expressed the belief that these representations can aid leaders in making ideas tangible to stakeholders.

I thought that the activities and discussions were an interesting metaphor for how organizations operate. Leaders could use these metaphors and explanations when describing an organizational shift or a new policy (Participant 10).

Additionally, the principle *adapt to changing conditions* strongly resonated with students; mainly, because administrators must adjust swiftly to unexpected events and outcomes. One of the students remarked that the discussions with peers, combined with the instructional materials, were beneficial to connect Life's Principles with leadership practices:

The informational cards helped me to see how nature and leadership are similar. For example, when we were discussing how the octopus adapts to situations in nature it made me realize as a leader, I must be willing and able to adapt and be flexible (Participant 4).

Furthermore, it was evident that students easily connected with the principle of *evolve to survive* which accentuates the concepts of reshuffling information, integrating the unexpected, and replicating strategies that work (Baumeister, 2014). Another student stated, "The activities brought about the importance of communication, collaboration, and flexibility to reach an organization's goals" (Participant 24). The theme of persistence was also prevalent in the students' comments. Leadership attributes such as perseverance and endurance are necessary to overcome challenging circumstances. These elements reinforce the idea of looking at the "big picture" when confronted with complex situations. A student shared that "Recognizing the choices, patterns, and cycles that create the greatest natural growth and persistence in a flourishing ecosystem or organism" (Participant 27).

Additional comments affiliated with Life's Principles are depicted in Appendix C. A final question in the survey asked students to provide suggestions to improve the overall

instructional activity. Their input will be used to enhance future activities and curriculum. Overall, both the quantitative and the qualitative data revealed that students recognized that nature's ingenuity and strategies are motivational and offer promising leadership tools.

Discussion

According to the results of this study, four areas of knowledge and practice revealed considerable growth and seemed to have influenced student leadership and managerial skills: *adapt to changing conditions, be locally attuned and responsive, integrate development with growth and discover nature's value.* Students' interest in, and observations of, biomimetic leadership were inspiring and informative, as well as their willingness to further explore these new theoretical and practical approaches. Comments such as, "It was interesting to learn how differently some of my classmates interpreted the questions compared to my interpretation. We created meaning together," (Participant 18) show that students began to make meaning by relating to nature and comparing their own experiences with the biomimetic leadership examples provided in the leadership cards exercise. As Densten and Gray (2001) noted, "The aim of reflective learning that integrates previous experiences with new learning should be to assist future leaders to adopt more sophisticated self-monitoring behaviors" (p. 121). Several students shared that they will employ this new knowledge at their school sites.

At the onset of the study, students' perspectives were focused on seeing the dangers of nature and how humans must control it in order to survive (i.e., the power and danger of predatory species and other violent aspects of nature). They also resisted the idea that nature has anything to offer their professional lives and assumed that leadership is an inherently human ability. In the end, students acknowledged the value of biomimetic leadership practices in leading and managing today's complex organizations. They discovered an approach that employs time-tested execution. Aspiring leaders must be prepared for the challenges that lie ahead; i.e., the impact of the climate crisis on students and communities, lack of resources, and equity gaps. Educating with nature-inspired, regenerative, sustainability, and social justice practices will offer them with the skills to advance their organizations and communities in their future endeavors. Biomimetic leadership reframes the current narrative in the leadership curricula by endorsing respect for ecological and cultural systems and promoting equitable access and well-being of all (Santone, 2019).

Limitations

There is a lack of previous studies on this subject. However, this particular limitation is an opportunity to identify new gaps in the literature. The sample population for this study included the graduate students at one educational leadership and administration program therefore the results cannot be generalized to other student populations. The design did not incorporate a control group; further iterations of this study should include a control and an experimental group. This design protocol would provide baseline data for the tested group, as well as exclude alternate reasons for any observed outcomes which will strengthen the reliability and validity of the project. While we are not aware of a specific biomimetic leadership assessment tool, other instruments may be available to evaluate student leadership behaviors and nature-inspired practices. As a final point, a longitudinal assessment may have provided data on the lasting effects of this leadership training after the participants completed the summer leadership synthesis course.

Results of this study present a guiding vision for a novel and stimulating leadership ideology. Biomimetic leadership inspires a mindset of conscientious possibility; this clarity enhances existing models of effective and ethical leadership even as it initiates principles for radical personal and organizational innovation. This approach contributes to the improvement of aspiring leaders' dispositions in the areas of systems thinking, empathy, social consciousness, critical thinking, equity-literate communication skills, self-efficacy and agency, creativity, and local and global ecological sustainability. The narrative describing the interdependence of ecology, social justice, and leadership is absent in the current leadership curriculum and national administrators standards. Introducing students to biomimetic leadership opens the space needed to discuss the connection among these topics.

As a first step, we recommend to include sustainability development in educational leadership programs. Three essential elements exist for sharing the biomimetic framework: *Ethos,* *(rE)connect*, and *Emulate* (Baumeister, 2014). *Ethos* refers to a leader's desire for a sustainable plan for the future. It encourages us to identify and promote the seeds of vision in others while making ethical and environmentally conscious choices. An educational leader that exemplifies a strong *Ethos* is someone who exudes appreciation for the resources, the spaces, and the people within the organization. This humble attunement allows a leader to anticipate and avoid unintended consequences. In the spirit of equity and diversity, all contributors are championed; the archetype for this behavior is drawn from a sustained study of the natural world. In the hands of educators, the disciplined and conscientious mindset of the *Ethos* framework has the potential to transform an entire culture.

The second essential element *rEconnect*, proposes that we must appreciate the reciprocal relationship between humankind and nature. Educational leaders may also create opportunities for community members to connect with nature through curiosity and observation. Reconnecting with nature can also minimize linguistic and cultural boundaries and provide restorative experiences. Kaplan (1995) adds, "Experience in natural environments can not only help mitigate stress; it can also prevent it through aiding the recovery of this essential resource" (p. 180). Therefore, we advise adding outdoor instructional activities to foster leaders' relation to nature, respect for natural systems, and attention to their own and their communities' well-being.

Lastly, *Emulate* establishes the literal and metaphorical relationship between leadership and biomimetics. Observational and scientific study generates "the how" for organizations to design nature-inspired solutions to organizational challenges. *Emulate* provides a fluid framework for sustainable, solution-oriented engagement as participants ask, "What would nature do?" As an example, a school district looking to advance student achievement must "evolve to survive" by "replicating strategies that work." Local Educational Agencies (LEA) are in the position to use district-wide data and "resource efficient" strategies to "build from the bottom up." Communication with Professional Learning Communities (PLCs) needs to be "locally attuned and responsive" as expectations are "broken down into benign units," with "life-friendly chemistry" for variance and autonomy. Charles (2004) points out that biological metaphors are alive and regenerative. In comparison, mechanical metaphors are dead and require energy and external force. Students' reaction to biological metaphors in the course of this study was enthusiastic. Consequently, we encourage the use of organic, living, dynamic metaphors to ignite creative problem solving.

To optimize biomimetic leadership is to incorporate all three elements—*Ethos,* r*Econnect*, and *Emulate—*into one's personal and professional lives. Such leadership empowers individuals to create sustainable organizations. Just as earth's atmosphere, geosphere, hydrosphere, and biosphere all work in harmony, biomimetic leaders utilize the inherent innovative strengths within the dimensions of Life's Principles and *Ethos,* r*Econnect*, and *Emulate*. Biomimetic awareness precedes compassionate and sustainable leadership.

ANDREA SOMOZA-NORTON is an assistant professor at California Polytechnic State University, School of Education, 1 Grand Ave. 02-110 San Luis Obispo, CA 93407. Email: asomozan@calpoly.edu

SHAWNA WHITFIELD is an educator at OceanView Elementary, 1208 Linda Drive Arroyo Grande, CA 93420. Email: shawna.whitfield@lmusd.org

References

Ackoff, R. L., & Rovin, S. (2005). *Beating the System: Using creativity to outsmart bureaucracies*. San Francisco, CA: Berrett-Koehler.

Bass, B. M. (1997). Does the transactional–transformational leadership paradigm transcend organizational and national boundaries? *American psychologist*, *52*(2), 130.

Baumeister, D. (2014). *Biomimicry resource handbook: A seed bank of best practices*. Biomimicry 3.8.

Benson, T., & Marlin, S. (2017) *The Habit-Forming Guide to Becoming a Systems Thinker*. Pittsburgh, PA: Systems Thinking Group, Inc.

Benyus, J. M. (1997). *Biomimicry*: *Innovation Inspired by Nature*. New York, NY: Morrow.

Bishop, R. (2017). *Chaos*. The Stanford Encyclopedia of Philosophy. Retrieved from https://plato.stanford.edu/archives/spr2017/entries/chaos/

Bogatyreva, O. & Shillerov, A. (2015) *Biomimetic Management: building a bridge between people and nature.* CreateSpace Independent Publishing Platform.

Bolman, L. G., & Deal, T. E. (2017). *Reframing organizations: Artistry, choice, and leadership*. Hoboken, NJ: John Wiley & Sons, Inc.

Capra, F., & Luisi, P. L. (2014). *The systems view of life: A unifying vision*. Cambridge: Cambridge University Press.

Charles, C., & Samples, B. (2004). *Coming Home. Community, Creativity, and Consciousness*. Fawnskin, Calif.: Personhood Press.

Creswell, J. W., & Clark, V. L. P. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA, US: Sage Publications, Inc.

Deming, W. E. (2000). *The New Economics for Industry, Government, Education*. Cambridge, MA: MIT Press.

Densten, I. L., & Gray, J. H. (2001). Leadership development and reflection: what is the connection? *International Journal of Educational Management*, *15*(3), 119-124.

Forrester, J. W. (2009). System dynamics: The classroom experience: Quotations from K-12 teachers. *Unpublished manuscript, Massachusetts Institute of Technology (MIT), Cambridge, MA*.

Glover, J., Friedman, H., & Jones, G. (2002). Adaptive leadership: When change is not enough (part one). *Organization Development Journal*, *20*(2), 15.

Hersey, P., & Blanchard, K. H. (1993). *Management of organizational behavior: Utilizing human resources*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Hutchins, G. (2012). *The nature of business: Redesigning for resilience*. New York: UIT Cambridge Ltd.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169-182.

Kellert, S. R., & Wilson, E. O. (Eds.). (1995). *The biophilia hypothesis*. Washington, D.C.: Island Press.

Miller, P. (2010). *The Smart Swarm: Using animal behaviour to organise our world.* London: Collins.

National Policy Board for Educational Administration (n.d.) Retrieved from http://npbea.org/

National Center for Educational Statistics (n.d.) Retrieved from https://nces.ed.gov/fastfacts/display.asp?id=28

Newman, A., Schwarz, G., Cooper, B., & Sendjaya, S. (2017). How servant leadership influences organizational citizenship behavior: The roles of LMX, empowerment, and proactive personality. *Journal of Business Ethics*, *145*(1), 49-62.

Provalis Research (n.d). Retrieved from https://provalisresearch.com/

Robinson, S. & Moraes Robinson, M. (2014) *Holonomics: Business Where People and Planet Matter*. Floris Books.

Santone, S. (2018). *Reframing the Curriculum: Design for Social Justice and Sustainability*. London: Routledge.

Senge, P. M. (2014). *The fifth discipline fieldbook: Strategies and tools for building a learning organization [electronic resource]*. [s.l.] Crown Publishing Group.

Senge, P. M., & Forrester, J. W. (1980). Tests for building confidence in system dynamics models. *System dynamics, TIMS studies in management sciences*, *14*, 209-228.

Solé, R. V., & Bascompte, J. (2006). *Self-Organization in Complex Ecosystems*. Princeton: Princeton University Press.

Tazzi, F. (2014). *Biomimicry in Organizations: Drawing inspiration from nature to find new efficient, effective and sustainable ways of managing business.* CreateSpace Independent Publishing Platform.

The Biomimicry Institute – Inspiring Sustainable Innovation. (n.d.). Retrieved from https://biomimicry.org/

United States Environmental Protection Agency (n.d.). *Learn about Sustainability*. Retrieved from https://www.epa.gov/sustainability/learn-about-sustainability#what

Vugt, M. V. (2006). Evolutionary Origins of Leadership and Followership. *Personality and Social Psychology Review, 10*(4), 354-371.

Waters Foundation (n.d). Retrieved from https://www.watersfoundation.org/press-releases/systems-thinking-institute-brings-unique-learning-opportunity-milwaukee-community-press-release-january-2018/

Welcome to Biomimicry for Social Innovation! *Nature's intelligence toward a human society.* (n.d.). Retrieved from https://bio-sis.net/

Wilson, E. O. (1978). *On Human Nature*. Cambridge, MA: Harvard University Press.

Wilson, E. O. (2000). *Sociobiology*. Cambridge, MA: Harvard University Press.

Woolley-Barker, T. (2017). *Teeming: How Superorganisms Work Together to Build Infinite Wealth on a Finite Planet (And Your Company Can Too)*. Ashland, Oregon: White Cloud Press.

APPENDIX A: Intersection of PSEL, Life's Principles and related designed lessons/strategies, and Essential Elements of Biomimicry Thinking

PSEL Standard	Life's Principles and related designed lessons/strategies	Essential Elements of Biomimicry Thinking
1. Mission, Vision, and Core Values Effective educational leaders develop, advocate, and enact a shared mission, vision, and core values of high-quality education and academic success and well-being of each student.	Integrate development with growth	*Ethos*
2. Ethics and Professional Norms Effective educational leaders act ethically and according to professional norms to promote each student's academic success and well-being.	Maintain integrity through self-renewal	*Ethos*
3. Equity and Cultural Responsiveness Effective educational leaders strive for equity of educational opportunity and culturally responsive practices to promote each student's academic success and well-being.	Incorporate diversity	*Ethos,* *Emulate,* *(rE)connect*
4. Curriculum, Instruction and Assessment Effective educational leaders develop and support intellectually rigorous and coherent systems of curriculum, instruction, and assessment to promote each student's academic success and well-being	Incorporate diversity Combine modular and nested components	*Ethos,* *Emulate,* *(rE)connect*
5. Community of Care and Support for Students Effective educational leaders cultivate an inclusive, caring, and supportive school community that promotes the academic success and well-being of each student.	Replicate strategies that work	*Emulate*

6. Professional Capacity of School Personnel Effective educational leaders develop the professional capacity and practice of school personnel to promote each student's academic success and well-being.	Cultivate cooperative relationships	*Emulate*
7. Professional Community for Teachers and Staff Effective educational leaders foster a professional community of teachers and other professional staff to promote each student's academic success and well-being.	Use feedback loops Use readily available materials and energy	*Ethos,* *Emulate*
8. Meaningful Engagement of Families and Community Effective educational leaders engage families and the community in meaningful, reciprocal, and mutually beneficial ways to promote each student's academic success and well-being.	Cultivate cooperative relationships	*Ethos,* *Emulate,* *(Re) Connect*
9. Operations and Management Effective educational leaders manage school operations and resources to promote each student's academic success and well-being	Build from the bottom up Use readily available materials and energy Reshuffle information	*Emulate*
10. School Improvement Effective educational leaders act as agents of continuous improvement to promote each student's academic success and well-being.	Leverage cycle processes Integrate the unexpected	*Emulate*

APPENDIX B: Biomimetic Leadership Dependent Variables

1. I believe communication is vital to the existence of the organization
2. I cultivate cooperative relationships
3. Interdependence and interconnectivity are important to me
4. I often reshuffle/reorganize information to generate innovation in my organization
5. I recognize the usefulness and value of feedback loops
6. I am locally attuned and responsive with my organization
7. I can adapt to changing conditions
8. I embrace unexpected situations
9. I am responsive to opportunities as they present themselves
10. I believe self-organization is important in achieving complex tasks
11. I accomplish big goals by building from the bottom up
12. I understand how resiliency can play a valuable part in stressful situation
13. I use readily available materials rather than generating new ones
14. I optimize rather than maximize
15. I replicate strategies that work
16. Nature plays an integral role in my life
17. I enjoy learning about nature
18. I can describe what biomimetic/biomimicry is
19. I am aware how biomimetic leadership can help me with decision-making and problem-solving in organizations
20. I am aware how biomimetic leadership can help with innovation in organizations
21. I am aware how biomimetic leadership can help integrate development with growth in organizations
22. I struggle to build interpersonal relationships at work
23. I prefer to work independently
24. I struggle with sudden or significant change
25. I accomplish big goals by starting with the big picture and top-level decisions
26. I struggle to think of new or innovative solutions to solve problems
27. Nature does not significantly interest me
28. I am skeptical that biomimicry can improve my leadership skills

Has this instructional activity helped you to acknowledge the role that nature's life principles could play in organizational leadership?
 ( ) Yes
 ( ) No
If YES, please explain how this instructional activity has helped you to acknowledge the role that nature's life principles could play in organizational leadership.
Once biomimicry/biomimetic was defined, did it aligned with some of your own leadership practices?
 ( ) Yes
 ( ) No
Please provide suggestions how we can improve this instructional activity

APPENDIX C: Students comments on Biomimetic Leadership

Life's Principles /Behaviors	Students comments
Adapt to changing conditions	It is more of a reminder to be present in the world and notice how life adapt to nature rather than the opposite. An organization should be fluid and responsive to the changing environment in order to achieve maximum efficiency.
	I have always felt that we could learn from nature, one of my favorite examples has always been learning from animal adaptations, like a lizard that loses its tail in an effort to escape capture or the oil on a duck's feathers. I see where we can, in fact, parallel our behaviors and adaptations from nature to be more successful.
Be locally attuned and responsive	Nature's life principles help organizations organize more efficiently and objectively. Utilizing diversity, cooperative relationships, and resilience are areas of interests.
	It centers the leader and allows the leader to look to nature to understand how management and/or leadership should work.
Be resource efficient (material and energy)	By noticing that nature works in sync with each are and everything is purposeful.
	Using the scenario cards was very helpful to discuss ways that nature translates into organizational leadership.
Evolve to survive	It reminded me that we can observe nature and mimic strategies in nature that can be successful for us in leadership.
	Connecting principles in nature to organizations in order to improve them.
Integrate development with growth	Recognizing the choices, patterns and cycles that create the greatest natural growth and persistence in a flourishing ecosystem or organism.
	I enjoy nature and have never thought of it in relation to the organization where I work. I think the concept of interconnected relationships in nature can be easily applied to my leadership methods.
Nature's Value	I have always loved nature and tried to learn lessons from natural systems. I now have a better language structure for explaining this practice to others. I also have multiple examples of exercises that I could replicate.
	I had not previously considered how nature could be used as a tool or how it mimics organizational leadership