Leadership Emergence and Impact on Open Source Software Project Success:

A Comparative Case Study

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ABSTRACT

Open source software (OSS) projects are typically considered to be 'leaderless' communities in which geographically dispersed volunteer participants produce software products and coordinate their work with the help of a variety of software tools. But is leadership really irrelevant in the OSS project development context? This paper examines the presence and emergence of leadership behaviors, and their impact on project success. Drawing from Avolio and Bass's full range leadership model, we provide a longitudinal case study of leadership behaviors in one highly successful OSS projects (freeCodeCamp, a project designed to help people "learn to code for free"[1]) and compare it to an unsuccessful project that was ultimately abandoned (Nylas Mail, "an open-source mail client"[2]). Interpersonal communication data were collected from 173 participants over a 22-month period, providing a dataset with 572 comments. These comments were categorized according to Bass and Avolio's multifactor leadership questionnaire (MLQ) resulting in 1465 unique coding events. Results indicated that leadership behavior was indeed present in both cases, and that it emerged over time. Moreover, consistent with transformational leadership theory, a significantly greater frequency of transformational leadership behavior was observed in the successful project (FCC), whereas transactional and laissez-faire leadership were more common in the unsuccessful project (Nylas). Theoretical and practical contributions are discussed.

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[1] https://github.com/freeCodeCamp/freeCodeCamp
[2] https://github.com/nylas/nylas-mail

INTRODUCTION

The success of the open source software (OSS) development approach is indisputable. Celebrated OSS projects such as Apache's web server and Linux's operating system have created exceptional business value (Shah, 2006). The number and variety of OSS projects has grown exponentially (Deshpande & Riehle, 2008), and the projected revenue of open source services is expected to triple between 2017 and 2022 to $US33 billion (Research and Markets., 2018). Despite these successes, however, it would be incorrect to conclude that OSS projects are generally successful; indeed, more than 98 percent reportedly become dormant within one year of launch (Berkholz, 2013). Given the potential significance yet exceedingly high failure rate of OSS projects, research that builds understanding about their success and failure is vital.

Can leadership help to explain OSS project success? Because these online communities are highly inclusive and rely on flattened hierarchies as opposed to traditionally structured organizational project teams (Dahlander & O'Mahony, 2011), some researchers have argued that OSS communities are 'leaderless' (Brafman & Beckstrom, 2006). However, this conclusion seems inconsistent with the large body of empirical research indicating a strong relationship between leadership and organizational performance in general (e.g., Stogdill, 1974; Bass, 1985; House, 1971; Kirkpatick & Locke, 1991; Fiedler, 1967; Vroom & Yetton, 1973). Transformational leadership behaviors in particular have been shown to play a special role in achieving above average results from followers (Bass, 1985; Avolio & Bass, 2002; Yang, Huang, & Wu, 2011; Antonakis, Avolio, & Sivasubramaniam, 2003; Bass, Avolio, Jung, & Berson, 2003), including in virtual team settings (Howell, Neufeld, & Avolio, 2005; Hoch & Kozlowski, 2014; Balthazard, Waldman, & Warren, 2009). Thus the available research suggests that leadership is essential to organizational performance.

However, while there have been numerous calls for research into leadership in open source communities (Von Hippel & Von Krogh, 2003; Bonaccorsi & Rossi, 2003), relatively little has appeared to date. One notable exception is a paper by Fleming and Waguespack (2007) that explored the links between human and social capital on the emergence of leaders in open source communities. We agree wholeheartedly with these authors, who observed that "open innovation communities rely heavily on strong leadership to function effectively and to resist splintering, forking, and balkanization … in order to understand the success of open innovation communities, we must understand the emergence of their leaders" (p. 165). While this paper provides excellent insights into how leadership roles are acquired in open communities, it is limited in its exclusive focus on leadership as a defined formal role. For example, Fleming and Waguespack refer to "assumption of a leadership position" (p. 169); consider a fairly limited set of actual behaviors such as physical presence, social brokerage, and boundary spanning; and rely on generalized quantitative analyses of a large dataset, trading off a more detailed local understanding. In contrast, our paper considers leadership from the perspective of full-range leadership theory, examines a wide set of actual leadership behaviors as expressed in written comments, and relies on qualitative comparative analyses of two contrasting case studies.

An additional relevant paper by O'Mahony and Ferraro (2007) focused on the role of governance systems on members' authority in an open source community. By unfolding the development process of shared governance systems, these authors studied how community members' conceptions of leadership change over time. For example, they found that technical contribution is more valued by community members in the early phases of project governance versus later phases. The paper used a single in-depth case study to provide a revealing explanation for the process of authority acquisition, focused on leadership turnover and member

conceptions of leadership change over time. Our paper, on the other hand, uses a comparative success-failure case study design to explore the emergence of leadership behaviors over time.

Thus, the purpose of this paper is to investigate the existence, impact, and emergence of leadership behaviors on OSS project success. We begin by identifying, instantiating, and categorizing leadership behaviors occurring in two OSS projects that have experienced diverse success outcomes. Next, we conduct a close inductive reading of team member communications over a 22-month period, and develop applied narrative accounts for each of the two cases to demonstrate how leadership emerged and evolved over time. Finally, we infer how varying leadership behaviors influenced OSS success.

THEORETICAL BACKGROUND AND PROPOSITIONS

Full Range Leadership Model

Avolio & Bass (2002) proposed the full range leadership model, comprised of leadership behaviors classified as transformational, transactional, and laissez-faire.

Transformational leadership focuses on "a sense of purpose and a feeling of family" (Bass & Avolio, 1993: 116), and "achieving superior results" (Avolio & Bass, 2002: 2). It has four action-oriented components: (1) charisma (consisting of *idealized influence* [the leader fosters trust, admiration, loyalty, and respect] and *inspirational motivation* [the leader inspires followers to pursue new ideas, e.g., by articulating a compelling vision of the future]); (2) intellectual stimulation (the leader challenges followers to engage in self-reflective and critical examination of commonly held notions); and (3) individualized consideration (the leader treats each follower as a whole being, e.g., by listening to their specific needs and concerns, and offering praise and encourages).

Transactional leadership includes some or all of the following behaviors: (1) contingent

reward (emphasizing contractual relationships with followers, such as doling out rewards based on completion of pre-specified goals); and (2) active management by exception (monitoring the follower's performance and concentrating on deviations from expectations); and (3) passive management-by-exception (reacting to a problem only when it becomes urgent).

Finally, laissez-faire leadership is effectively non-leadership (i.e., "let them do what they want"), resulting in leaders who are considered absent, unavailable, and ineffective.

Transformational and transactional leadership behaviors are both positively related to team-level performance (Bass et al., 2003), though transformational leadership has been associated with exceptional follower performance (Avolio & Bass, 2002). Leadership style has been shown to influence followers' perceptions in the information system development process (Eseryel & Eseryel, 2013). At the project team level, leadership style has impacted the success rates of online creative collaboration projects (Luther & Bruckman, 2011). Leader inspiration has been shown to accelerate the development of socialized relationships with followers (Joshi, Lazarova, & Liao, 2009). Organizationally, different leadership styles have dramatically reshaped cultures and structures (Bass & Avolio, 1993). In all, transformational, transactional, and laissez-faire leadership significantly impact performance, in differing ways.

Understanding the relationship between leadership and OSS project performance is important for two reasons. First, with virtually exclusive reliance on computer-mediated communication in OSS projects, it is important to understand how leadership behaviors differ compared to what happens in traditional face-to-face settings. For example, transformational leadership has been shown to have a stronger impact on team performance in virtual teams than face-to-face teams (Purvanova & Bono, 2009). Moreover, open source teams generally have a more dynamic, diverse, and evolving structure compared to traditional organizational teams.

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Leadership emergence for OSS team members, who rely exclusively on virtual collaboration with far-flung team mates, might occur differently from that of traditionally-centralized organizational teams.

Balthazard et al. (2009) argued that an OSS project is a special type of virtual team in which leaders are not assigned, and that uses implicit leadership theories to examine the emergence of transformational leadership in virtual teams. Implicit leadership theories suggest that leaders surface either in an 'ascribed' way (by demonstrating values consistent with leadership prototypes), or in an 'achieved' way (by providing practical value to the team and project) (Offermann, Kennedy, & Wirtz, 1994). Informal leadership emergence may also be associated with individual traits, possibly moderated by gender (Neubert &Taggar, 2004), although we suspect that in the OSS context gender may not have much or any effect because this information is frequently unknown when individual developers interact virtually.

Taken together, the foregoing research suggests that even though OSS projects usually do not have a formally assigned leader, as individuals engage in (ascribed or achieved) leadership behaviors, they will naturally emerge as leaders. Therefore, we posit:

Proposition 1: Leadership behaviors emerge naturally in the OSS context.

OSS Success

IS success may be generally understood as a multidimensional construct consisting of system quality, information quality, service quality, use, user satisfaction, and net benefits (DeLone & McLean, 1992; Petter, DeLone, & McLean, 2008)—dimensions that must be adapted to specific contexts (DeLone & Mclean, 2003).

In the case of open source projects, success may be defined in three ways. First, achieving project goals is an important aspect of OSS success. This may be seen, for example, by

major software releases (Crowston, Annabi, and Howison, 2003), or by percentage of task completion (Subramanian and Soh, 2006). It is important to note that OSS 'failures' (such as project abandonment) are sometimes instrumental to subsequent 'successes', whereas an ongoing project may not be having any positive impact—and so success and failure might be construed as 'dual factors' (Cenfetelli, 2004). Second, community service quality, the extent to which developers actively provide help and feedback during the creation stage of OSS packages (Lee, Kim, & Gupta, 2009), is an important dimension of OSS success. Finally, the extent to which an OSS product is ultimately adopted is a critical success factor. OSS use corresponds to the DeLone and McLean's net benefits stage because it indicates to what extent an OSS project has raised attention and led to users benefits.

Previous OSS research has studied individual developers' motivations to participate in OSS projects (Hars & Ou, 2002; Hertel, Niedner, & Herrmann, 2003; Wu, Gerlach, & Young, 2007; Fang & Neufeld, 2009), leadership emergence in OSS communities (Blincoe, Sheoran, Goggins, Petakovic, & Damian, 2016; Li et al., 2012), and OSS success writ large (e.g., Weber, 2004; Lerner & Tirole, 2002; Crowston et al., 2003). However, it is still unclear what leadership styles and behaviors are related to success and failure outcomes. According to transformational leadership theory, we anticipate that leadership style will be associated with OSS project success – specifically, that transformational leadership behaviors will have the strongest positive association with success; that transactional leadership will have a less powerful but still positive impact; and that laissez-faire leadership will be negatively associated with OSS success. Thus:

> *Proposition 2: Leadership style is associated with OSS project success (most strongly for transformational behaviors, less strongly for transactional behaviors, and negatively for laissez-faire behaviors).*

METHODS

Dataset and Procedures

To investigate open source leadership and its impact on success, we turned to GitHub, the world's leading OSS development platform. GitHub was founded in 2008 and currently hosts over 20 million publicly accessible project repositories, with 31 million registered users (www.github.com/about). We chose to select one successful and one failed OSS case in order to uncover between-case variations.

To identify a candidate projects, we began by considering 'star count', a popularity metric that simply reflects the number of users who have 'starred' a project, effectively adding it to their favorites list (see table 1). Among the six projects with over 100,000 stars, two additional selection criteria were used: applied nature of project objectives (we wanted to study a project with a deliverable that was broadly understandable and interesting), and community size (to insure a substantial number of interactions between OSS members to support an in-depth study). Consequently, we chose a project called *freeCodeCamp* (FCC), which was in fact the single most popular project on GitHub with nearly 300,000 stars. FCC's mission:

> *"To help people learn to code for free. We accomplish this by creating thousands*
> *of videos, articles, and interactive coding lessons - all freely available to the*
> *public. We also have thousands of freeCodeCamp study groups around the*
> *world."* (https://www.freecodecamp.org/)

Insert Table 1 about here

Selecting a failure case was more challenging, given the large number of projects with low star counts and minimal activity. We looked for a project that was launched in the same

general time period as FCC, and that had a similar early trajectory (in terms of general applied interest, contributor engagement, etc.) – but a project that later stumbled and failed. Ultimately, we identified *Nylas Mail* (Nylas) as the failure case. Nylas was an open source mail client that helped users to manage several email accounts in one desktop application, and provided many desirable features such as language translation, an emoji keyboard, phishing detection, and more. Despite a promising start, Nylas development became dormant in the spring of 2017, 31 months after its creation. A summary of the two projects is shown in table 2.

Insert Table 2 about here

Project data were assembled from three sources. First, the project homepage provided general information and statistics such as age, intended audience, software product, and license type. Second, the GitHub issues bug tracker provided an historical archive of all interactions between contributors including progress reports, organization tasks, and solutions to problems, providing insights into core members' leadership styles. For the FCC project we focused on the top three most-commented issues (305 posts), and for the Nylas project we analyzed the top two most-commented issues as well as the final issues related to the project's closure (267 posts). Third, the developer chatroom, a freeform communication tool that enabled online real-time dialogue among developers, was used to triangulate and gain further insight into community members' communication styles.

We employed a comparative, descriptive case study approach (Sarker, Xiao, Beaulieu, & Lee, 2018; Yin, 2009). The unit of analysis was the OSS project, and our objective was to compare emergent leadership behaviors in a successful case (FCC), to those of an unsuccessful case (Nylas). For both cases, data were read broadly and then deeply, and a descriptive narrative

was developed to provide a preliminary understanding of the flow of events. A directional

content analysis was conducted using NVivo qualitative software and employing a theoretical

sampling approach (Eisenhardt, 1989). Our qualitative coding scheme was adapted from the

multifactor leadership questionnaire (MLQ) (Bass & Avolio, 1995) to assess incidents of

transformational, transactional, and non-leadership behaviors (table 3). The MLQ is a widely

validated scale used in both leadership research and applied settings (Avolio, Bass, & Jung,

1999; Purvanova & Bono, 2009; Bass et al., 2003).

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RESULTS

A portion of the descriptive narrative for one issue in FCC, and one issue in Nylas, is

provided in table 4.

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Contextual reading of 572 GitHub posts across the two projects resulted in a total of

1,465 leadership MLQ-based codes in the FCC and Nylas cases (table 5). After completing a

training session, an independent rater cross-coded a subset of 56 comments, and achieved inter-

rater agreement of 0.83 (exceeding the general requirement of 0.70, Miles & Hubermann, 1984).

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Emergent Leadership

We observed a pattern of leadership emergence and evolution among 12 individuals

across the two cases; there were also more leaders at the end of each issue compared to the

beginning. Furthermore, the number of coded behaviors of these emergent leaders also increased as the issues progressed. These findings are broadly consistent with P1, that leadership emerges naturally in the OSS context.

In-depth analysis of interpersonal discussions provided further support for the first proposition. Considered independently and anecdotally, many of these interactions at first appeared mundane and unremarkable. However, when evaluated contextually and longitudinally it was apparent that certain individuals in both cases were exhibiting substantive leadership behaviors.

As one example of natural leadership emergence, FCC contributor @QuincyLarson proposed to merge online chat rooms and received 20 replies with suggestions and objections over a three-month period, but no resolution was reached. Eventually, at the beginning of the fourth month of the issue, developer @abhisekp volunteered to solve the problem by making practical technical recommendations and demonstrating the way to obtain room id's. Next, @QuincyLarson asked if @abhisekp were interested in writing the script, to which @abhisekp quickly responded positively, "I will figure it out and write the script". In this example, @QuincyLarson provided initial leadership by coordinating developer activity, but @abhisekp also demonstrated gradual, emergent leadership. As time went by, during the fifth month @abhisekp took on increasing responsibility by organizing the online discussion and directing other developers. Later, @abhisekp released a preliminary solution to the issue, led further discussions on technical issues, and then in the sixth month announced the final solution.

As a second example of emergent leadership, FCC developer @no-stack-dub-sack reported that a project calculator was not giving the correct output. Numerous FCC community members joined the conversation and tried to tackle the bug from different angles, posting 11

comments within three days. Among these members, @SamAI-Software appeared as a leader by proposing pragmatic to-do steps (e.g., "TODO: Add info to the challenge"), organizing a community vote ("Vote: Windows style"), offering enthusiastic praise and encouragement before gently identifying criticisms (e.g., "@swapsha96, yes, now it looks much better! [thumbs-up emoji]. However, there is a UX issue …"), and consistently offering detailed feedback and direction over the 6-month period of the issue. @SamAI-Software's leadership role became increasingly prominent as he changed from seeking the advice of others, to offering positive feedback during the first week of the issue. @SamAI-Software encouraged discussion among developers, recognized developers' technical contribution, and empowered individual developers with constructive criticism during the first month. Other developers demonstrated their respect to @SamAI-Software's leadership by regularly seeking his opinions and advice. @SamAI-Software's leadership clearly emerged and evolved over time.

Emergent leadership was also apparent in the Nylas project. When Nylas member @kylehayes reported that they could not download Red Hat Package Manager (RPM) files, eight replies were posted within three days, half of which simply confirmed the issue. Meanwhile, another Nylas developer, @Zeklandia, weighed in: "I've been trying to build it myself but it always fails at script/grunt mkrpm" (in other words, @Zeklandia tried running the code to build the software application on their local computer, but the process was not working properly). @Zeklandia received 10 replies in the ensuing five days, and after discussions with other members, discovered a solution, and subsequently assisted other members (i.e., "you can fix that by using rpmrebuild …"). In this scenario, @Zeklandia did not hold any leadership role at the beginning of this issue, but became a prominent leader by independently proposing technical solutions and enthusiastically helping other developers.

This analysis provides preliminary support for the first proposition: leadership behaviors emerged naturally over time in both the FCC and Nylas open source projects.

Leadership Style and Project Success

Cross-case analyses provided support for the second proposition (table 6). Transformational leadership behaviors were relatively more frequent in the FCC community (94.9% of all codes) versus Nylas (68.0% of all codes), whereas transactional and laissez-faire behaviors occurred more frequently among Nylas contributors (13.3% and 18.6%, respectively) compared to those in the FCC community (4.0% and 1.1%, respectively).

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Further, as shown by crosstabulation results in table 7, the frequency of demonstrated transformational, transactional, and laissez-faire behaviors differed significantly across the two cases ($x^2 = 210.7$, p < .001).

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Transformational leadership. The foregoing quantitative summary was supported by qualitative analyses. For example, FCC developer @QuincyLarson exhibited charismatic leadership by attributing issue resolution to all members ("thanks everyone!"), and by repeatedly emphasizing collective efforts ("our goal is to make sure we've backed up all the rooms"). Another FCC leader @no-stack-dub-sack employed intellectual stimulation by actively seeking others' opinions ("any thoughts?") after proposing his own technical solutions. Likewise, FCC developer @SamAI-Software showed individualized consideration by coaching and mentoring other developers ("@evaristoc … instead of making a big change at once, let's make these

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changes step-by-step. For the start we can …"). All three dimensions of transformational leadership behaviors were frequently reflected in the FCC project.

Similarly, Nylas developer @jstejada demonstrated charismatic/inspirational leadership by raising awareness about the search function issue, and promoting discussion of potential solutions. @jstejada also showed intellectual stimulation and individualized consideration as he taught individual followers how to advance the issue ("hi @ewiggin -- thanks for reporting this. Could you open the DevTools and pull the logs name out …?").

While charismatic/inspirational behaviors were evident in both FCC and Nylas cases in similar proportions (48.8% and 45.9%, respectively), the relative frequency of intellectual stimulation and individualized consideration were twice as common in FCC (9.9% and 36.1%, respectively) compared to Nylas (5.1% and 17.0%, respectively). In other words, FCC leaders were much more likely to engage in intellectual stimulation (e.g., examine assumptions, seek different views, suggest new ideas, suggest different angles) and individualized consideration (e.g., pay individual attention, focus on people's strengths, teaching and coaching, and differentiating among individuals), compared to Nylas leaders.

Transactional leadership. Transactional leadership occurred in both projects, but less frequently for FCC compared to Nylas (4.0% and 13.3%, respectively). For instance, FCC developer @QuincyLarson appeared to engage in tit-for-tat contingent reward behavior while assisting other members ("you can just dump them into a local directory and I can retrieve them manually and put them on bittorrent later"), whereas FCC developer @Paddylandau engaged in active management by exception behaviors by monitoring other developers' feedback and clarifying potential misunderstandings ("@nvnellore This applies only to Chromium and, by extension, Chrome. No other browser gives this problem").

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These kinds of transactional behaviors were observed much more frequently in Nylas. In one instance, developer @bengotow recognized followers' achievement and effort ("thanks for taking the time to report issues here"). In another, developer @jamesnetherton challenged the quality of another member's work ("hacking up the RPM with Alien looks pretty dodgy to me"). Active management-by-exception behaviors were much more frequent in Nylas (11.9%) compared to FCC (1.3%). Nylas leaders were more likely than FCC leaders to actively monitor task execution and report on potential problems. In all, while transactional leadership behaviors occurred relatively infrequently in both projects, they were significantly more common in Nylas as a proportion of total coding events. These findings are consistent with previous research showing that transactional leadership is not as effective as transformational leadership in terms of inspiring followers (Avolio & Bass, 2002).

Laissez-Faire Leadership. Laissez-faire behaviors were rare in FCC, and common in Nylas (1.1% and 18.6%, respectively). Nylas developers were frequently absent when needed. At one point a group of core Nylas developers completely stopped maintaining the project, neither conveying this decision to other community members, nor responding to inquiries about project status (@lxalln stated, "it's a shame that nobody is communicating with the community"). Nylas leader @jstejada only showed up twice during the first two months of a new issue (regarding a disabled search function). As a result, @JoanPlume complained, "What is the solution !!". Some Nylas leaders delayed responding and reacted only after the problem had become serious.

Several factors played an important role in the differing success / failure results across the two projects. First, there were more core developers with relatively strong technical abilities in FCC, who were motivated and willing to solve issues as they arose. On the contrary, most Nylas members limited their contribution to raising awareness, but then seemingly waited for someone

else to provide the solution. Second, communication patterns differed significantly across the two projects. FCC developers consistently responded to each other promptly, whereas Nylas members were slow to respond, even to critical issues, and in some cases went silent for long periods of time. Third, FCC members had relatively higher trust level and better social relationships among themselves, regularly emphasizing the collective mission, and facilitating mutual collaboration. On the other hand, it seemed that many Nylas members acted like 'customers' who expected their 'vendor' to solve problems for them – whereas most Nylas leaders avoided responding to problems, until a problem became serious.

DISCUSSION

This research provides preliminary evidence that leadership plays an essential role in determining OSS project success and failure. Our inspection of interpersonal communications revealed that leadership behavior clearly occurred and emerged over time, and that it differed substantively across the two cases. These findings contribute to the information systems literature insofar as the large and expanding open source / online community / virtual team context is fundamentally reliant on information and communication technologies. The paper also adds to the leadership literature by demonstrating the critical role of transformational leadership theory, and in particular the role of differentiated leadership behaviors, to project success.

The findings here are most relevant to open source project teams. If leadership behaviors emerge naturally and are necessary for project success, and if transformational behaviors have an outsized influence on success while laissez-faire behaviors are more likely to result in failure, then it would make good sense to teach and encourage use of transformational behaviors in open source teams.

These findings also offer general guidance to inclusive organizations that rely on

distributed, peer-oriented, 'leaderless' team structures. Importantly, it might not be necessary to assign a formal leader in virtual teams, since leaders may emerge naturally, and in fact making formal leadership assignments could be counter-productive. Instead, offering transformational training exercises to all members of a team could instill positive leadership capacities, while simultaneously allowing positive leadership behaviors to emerge naturally.

Finally, open source and virtual team leaders, whether formally assigned or emergent, may benefit by reflecting on and adjusting their own personal leadership behaviors – by adopting more transformational approaches, eliminating laissez-faire behaviors, and using transactional behaviors selectively.

The primary strengths of this paper include use of longitudinal data, in-depth comparative case study, and adoption of the widely validated MLQ scale as a baseline for the qualitative coding schema. Dimensions of transformational, transactional, and non-leadership were analyzed to extend our understanding of how leadership impacts success outcomes in inclusive open communities. Limitations are primarily related to our reliance on inductive case study, which means that results are not broadly generalizable to other situations. Additional research is necessary to widen understanding of the leadership-success relationship in online communities, and to boost external validity. Such research should utilize a variety of inductive and deductive approaches, and a wider range of research contexts, to examine emergent leadership behaviors and outcomes in other online communities (e.g., other OSS platforms such as BitBucket and SourceForge; social communities such as Facebook and LinkedIn; reference communities such as Wikipedia and WebMD; and highly dispersed organizational virtual teams). Furthermore, while this study was based on real online conversations that occurred between project team members, it was entirely dependent on secondary data. Future research into this topic would

benefit from including primary data, in order to allow the researchers to directly interact and validate findings with participants in real-time.

In summary, this paper investigates the impact of leadership in the OSS context. Results show that transformational, transactional, and laissez-faire leadership behaviors emerge naturally, with varying impacts on OSS project success – most notably, that transformational leadership has a significantly higher impact in the case of OSS project success, whereas transactional and laissez-faire leadership were more common in the case of OSS project failure. Additional research into virtual leadership is needed, considering the growing popularity and use of online communities and distributed teams.

Table 1: Github Star Count Distribution

Star Count	# Repositories	%
0	14,929,371	70.7%
1-100	6,046,533	28.6%
101-500	100,142	0.5%
501-1,000	16,883	0.1%
1,001-10,000	16,537	0.1%
10,001-100,000	960	0.0%
More than 100,000	6	0.0%
Total Projects	**21,110,432**	**100.0%**

Table 2: freeCodeCamp vs Nylas Mail Characteristics

Initial Characteristics	FCC	Nylas
Creation Date	2014-12-24	2014-10-16
First 3 months:		
# commits	52	17
# issues closed during this period	25	10
# stars	1	84
Later Characteristics		
Most recent month	2018-12	2018-12
# active pull requests	1421	0
# active issues	104	1
# merged pull requests	1274	0
# closed issues	147	1
# new issues	73	0
# proposed pull requests	31	0
# stars	296,644	24,210
Status	continuing	dormant

Table 3 – Coding Schema for OSS Leadership

Adapted from Bass & Avolio's Multifactor Leadership Questionnaire (1995)

TRANSFORMATIONAL LEADERSHIP	TRANSACTIONAL LEADERSHIP
Charisma – the leader:	**Contingent Reward – the leader:**
… is proud of follower (CH1)	… clarifies rewards for followers (CR1)
… goes beyond self-interest (CH2)	… assists, based on follower effort (CR2)
… draws follower respect (CH3)	… rewards for achievements (CR3)
… displays power and confidence (CH4)	… recognizes follower achievements (CR4)
… talks about values (CH5)	
… serves as a role model (CH6)	**Management-by-Exception, Active - the leader:**
… considers morals/ethics in decision-making (CH7)	… focuses on follower mistakes (MA1)
… emphasizes the collective mission (CH8)	… puts out fires, when they arise (MA2)
… talks optimistically about the future (CH9)	… tracks follower mistakes (MA3)
… expresses confidence about the goal (CH10)	… concentrates on failures (MA4)
… talks enthusiastically and excitedly (CH11)	
… arouses awareness about key issues (CH12)	**LAISSEZ-FAIRE LEADERSHIP**
Intellectual Stimulation – the leader:	**Passive-Avoidant - the leader:**
… examines assumptions & offers alternatives (IS1)	… reacts to problems, if serious (PA1)
… seeks different views & invites challenges (IS2)	… reacts to failure (PA2)
… suggests new ideas and solutions (IS3)	… acts per 'if it ain't broke, don't fix it' (PA3)
… suggests different angles, open to change (IS4)	… reacts to problems, only when chronic (PA4)
	… avoids involvement (PA5)
Individualized Consideration – the leader:	… is absent when needed (PA6)
… individualizes attention to follower (IC1)	… avoids deciding (PA7)
… focuses on the follower's strengths (IC2)	… delays responding (PA8)
… teaches and coaches, constructively (IC3)	
… differentiates among followers (IC4)	

Table 4 – Case Narratives

Success: freeCodeCamp (FCC)	Failure: Nylas Mail (Nylas)
Issue: Application calculator does not give correct output. **Background.** On Aug 10 2016, member @no-stack-dub-sack pointed out a bug: the application's calculator did not give the correct output. Several people joined the conversation and tried to tackle the bug from different angles. @SamAI-Software asked @raisedadead about the possibility of fixing the code. @raisedadead responded with possible bug fix procedures and added a label to the issue. **Phase 1-Active Discussion.** After hearing back from @raisedadead, @SamAI-Software made a to-do list and proposed a vote on Aug 11 2016. Member @oalhait volunteered to help, but did not show up later. Another contributor @swapsha96 tested the algorithm in his forked project. @swapsha96 discussed with leader @SamAI-Software inclusion of several detailed functions in the code. Between Aug 12 2016 and Aug 19 2016, their discussion had a typical 3-step pattern. <u>First</u>, @swapsha96 improved the code and repeatedly requested @SamAI-Software's opinions, demonstrating respect. <u>Second</u>, @SamAI-Software replied, enthusiastically praising @swapsha96's achievements, and then offering suggestions for improving bugs in the codes. When @SamAI-Software pointed out the bugs and mistakes, he put himself into the shoes of @swapsha96. For example, when @swapsha96 apologized, @SamAI-Software mentioned that he had the same experience of making new bugs while fixing bugs, showing empathy. @SamAI-Software also mentioned that the quality assurance team has a mission to help to debug, and so they could pursue the problem collectively. <u>Third</u>, @swapsha96 thanked SamAI-Software for the detailed feedback. @swapsha96's last message, on Aug 19 2016, was to ask if his new code functioned well. @SamAI-Software replied affirmatively on the same day, but @swapsha96 did not show up anymore. **Phase 2-Team Effort.** @no-stack-dub-sack joined the discussion with his own code on Aug 18 2016. He asked some questions about the work, to which @swapsha96 replied, "I work along with @SamAI-Software", suggesting that he regarded himself to be working in a peer-based team with @SamAI-Software …	**Issue:** Search does not work (no search results) **Background.** On Dec 18 2015, member @Ewiggin raised a new issue: he could not successfully search on emails in the application's inbox. On the same day, contributor @jstejada suggested a potential solution, and added labels to the issue. **Phase 1-Complaints.** Thirteen community members subsequently left comments to complain that they had the same issue, and three of them specifically mentioned @jstejada in their comments, but they did not attempt to solve the issue by themselves. @jstejada remained silent until Feb 2 2016, when he asked community members for clarification about their questions. For example, "it seems that this issue is occurring only with IMAP accounts? Is anyone experiencing this issue with another type of account, like Gmail or Exchange?". Twenty replies were posted (four on the same day), yet @jstejada did not reappear until Feb 29, nearly one month later. Some members seemed frustrated, e.g., @JoanPlume commented on Feb 21, "What is the solution !!", and @blakkheimgw commented on Feb 27, "… The bug report is 2 months old and no one is assigned to". When @jstejada appeared on Feb 29, he appeared to only change the title to be more accurate, but did not leave any further comments or suggestions. Some community members such as @tartley and @robr3rd offered detailed descriptions of the issue, and member @bonaldi attempted to analyze the reasons for the bug. However, no one attempted to provide technical solutions. **Phase 2-New Release.** Member @robr3rd commented on Feb 29 that "@jstejada As I just happened to see you edit the title, if you happen to swing by this area again, please consider …". On Mar 2, @jstejada once again changed the title of the issue, but surprisingly he did not reply to @robr3rd, who asked if other community members were still experiencing this issue (confirmed over the next 10 days by 10 community members). On Mar 18, jstejada again changed the title, and disappeared. A number of community members mentioned only their own computer settings and if they experienced the issue, which made the Issue look chaotic. At that time, @robr3rd summarized the current situation of the issue …

Table 5 – Inter-Rater Reliability

TRANSFORMATIONAL LEADERSHIP (TF)	ƒ	% of TF	IRR
Charisma/Inspirational	73	63.5	0.84
Intellectual Stimulation	13	11.3	0.77
Individualized Consideration	29	25.2	0.83
Subtotal	115		
TRANSACTIONAL LEADERSHIP (TA)		**% of TA**	**IRR**
Contingent Reward	9	56.3	0.89
Management-by-Exception, Active	7	43.8	0.86
Subtotal	16		
LAISSEZ-FAIRE LEADERSHIP (LF)		**% of LF**	**IRR**
Passive-Avoidant	8	100.0	0.88
Total			**0.83**

$ƒ$: common cross-coding frequencies between rater 1 and rater 2.

Table 6 – Leadership Behavior Frequencies

	FCC		Nylas	
TRANSFORMATIONAL LEADERSHIP (TF)	**#**	**% total**	**#**	**% total**
Charisma/Inspirational	477	48.8%	224	45.9%
Intellectual Stimulation	97	9.9%	25	5.1%
Individualized Consideration	353	36.1%	83	17.0%
Subtotal	927	94.9%	332	68.0%
TRANSACTIONAL LEADERSHIP (TA)				
Contingent Reward	26	2.7%	7	1.4%
Management-by-Exception, Active	13	1.3%	58	11.9%
Subtotal	39	4.0%	65	13.3%
LAISSEZ-FAIRE LEADERSHIP (LF)				
Passive-Avoidant	11	1.1%	91	18.6%
Total	**977**	**100.0%**	**488**	**100.0%**

Table 7 – Contingency Table

ACTUAL	Transform.	Transact.	Laissez-Faire	Total	%
FCC	927	39	11	**977**	66.7%
Nylas	332	65	91	**488**	33.3%
Total	**1259**	**104**	**102**	1465	
%	85.9%	7.1%	7.0%		

EXPECTED	Transform.	Transact.	Laissez-Faire	
FCC	839.6	69.4	68.0	
Nylas	419.4	34.6	34.0	

x^2	Transform.	Transact.	Laissez-Faire	
FCC	9.1	13.3	47.8	
Nylas	18.2	26.6	95.7	

Overall x^2	**210.7**	
p	**1.77E-46**	

Transform: the number of transformational leadership behaviors.

Transact: the number of transactional leadership behaviors.

Laissez-Faire: the number of laissez-Faire leadership behaviors.

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