IMPACT OF MULTI-ROLE PLAYING ON INDIVIDUAL INNOVATIVENESS IN OPEN SOURCE SOFTWARE (OSS) COMMUNITY: AN EMPIRICAL TEST

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ABSTRACT

The purpose of this paper is to investigate the impact of multi-role playing on individual innovativeness in the context of open source software (OSS) community. Based on community ecological, cross functional team, and social network perspectives, this paper develops the hypothesis that multi-role playing positively impacts individual innovativeness. An empirical test is conducted with the award-winning open source web Content Management System (CMS) Drupal community as the data source and it is found that the multi-role playing hypothesis is strongly supported in this test. This finding with a focus on individual innovativeness complements existing project level studies in the context of OSS development. Implications for research and practice are discussed at the end.

Keywords: Multi-Role Playing, Open Source Software, Drupal, Innovativeness, Content Management System

INTRODUCTION

OSS development has been a valid model for more than 25 years [19]. There are at least two steams of research in this field. First, there are numerous studies focusing on individual level motivation and participation in OSS development (e.g., [4][5][10][13][16][21][25][31]). In addition, why commercial companies are willing to contribute to the OSS development was also investigated [1]. The second stream of studies focuses on factors impacting OSS project success. For example, Stewart and Gosain [28] investigated how OSS community values, norms, and beliefs influence OSS project effectiveness in terms of attracting and retaining team members and guiding project development towards success. Some other researchers took the social network perspective to investigate this issue. For example, Grewal, Lilien, and Mallapragada [12] studied the impact of network embeddedness on project success and found OSS projects

do have different levels of network embeddedness and the level of embeddedness has stronger impact on technical success than commercial success. Singh, Tan, and Mookerjee [27] used longitudinal data to examine the impact on OSS project success of project team internal/external cohesion and other network based variables. Daniel, Agarwal, and Stewart [7] investigated how role-based variety in an OSS project team impacts community engagement for the success of OSS projects. All these studies have their dependent and independent variables at the project level.

The current study follows this second research stream in that it also investigates factors impacting the OSS project success and intends to complement previous studies. The dependent variable in this study is similar to the technical success in Grewal, et al. [12], but it is about the individual innovativeness in the OSS community. The key independent variable is the extent of the multi-role playing by individuals instead of team level variables such as the extent of technological background diversity

of external contacts in [12], the project team internal/external cohesion, the number of direct and indirect external contacts, and the technological diversity of project team members in [27]. Further, the empirical test in this paper measures the multi-role playing variable using three roles instead of two roles in [7], which may provide evidence on the impact of role variety at the individual level on OSS project success in the context of an OSS community. The following sections will elaborate on theoretical development, research method, and results discussions.

THEORETICAL DEVELOPMENT: IMPACT OF MULTI-ROLE PLAYING ON INDIVIDUAL INNOVATIVENESS IN THE CONTEXT OF OSS COMMUNITY

Community Ecological Perspective: This perspective emphasizes the investigation of the birth of new and death of existing populations in a community, the inter-dependent symbiotic or competitive relationships among different populations of a community, and the interactions among different communities [2]. This perspective has been applied to study a variety of communities including the PC community consisting of populations such as software producers, PC manufacturers, disk driver producers, and users [29][30], the health care organization community consisting of populations such as insurance companies, hospitals, HMOs, and relevant agencies [22], the community of craft and industrial labor unions [15], the community of newspapers and political parties [8], and the community of financial institutions including the population of financial cops and that of banks in Singapore [9].

Since multiple interactive populations such as developers, clients, and educators co-exist in an OSS community, application of this community ecological perspective may help explore how these populations interact to generate synergistic effects in the context of OSS community. Indeed, based on this perspective, in the research of Internet standard evolution, with the assumptions that each standard institution represents a population of work groups and several institutions form the Internet standard making community, Nickerson and zur Muehlen [17] investigated the impact on Internet standards evolution of the standard making community members' movements among work groups within the same and across different institutions. They found that the ecological perspective applies well to explain the lengthy process of Internet standard making. One of their findings is that as

members of the Internet standard making community move between work groups within the same or across different populations, they can be treated as playing different roles in a variety of groups/populations and carrying ideas from one group/population to another and these movements can foster synergistic effects in terms of enabling the development of the most appropriate Internet standards. It is believed that this perspective can also be applied to support the key hypothesis (i.e., multiple-role playing positively impacts individual innovativeness in the context of OSS community) in this paper since multi-role playing implies that OSS community members participate in activities in multiple populations, which may very well facilitate innovative idea generation and enable thorough communications among those playing different roles as what has been found in the Internet standard making community by Nickerson and zur Muehlen [17].

Cross-Functional Team Perspective: Sethi, Smith, and Park's [23] study on how a cross-functional team may influence the innovativeness of product design provides a theoretical foundation based on which multi-role playing can be hypothesized to positively impact the individual innovativeness in an OSS community. First, if a community may be loosely treated as an organization, then populations within the community can be regarded as different departments within the organization. Second, since multi-role playing members in this community are simultaneously working in different populations, then these members may be treated as forming a virtual cross-functional team representing different functional perspectives (such as users' and code developers' perspectives in an OSS community).

With this kind of virtual cross-functional team for OSS projects, there are two benefits. First, since multi-role playing members are involved in different functional activities and have exchange relationships with other members in a variety of functions, diverse views and perspectives are more easily absorbed during the OSS development process. Second, due to the multi-perspectives each member in the virtual cross-functional team brings to the team, he/she less likely holds deeply rooted biases and stereotypes toward those from other functions /populations, which enables the establishment of a superordinate identity within the virtual cross-functional team. Both of the above two benefits are positively related to innovativeness. Indeed, Pinto, Pinto, and Prescott [18] empirically identified the positive impact of superordinate goals on cross-functional cooperation and perceived task performance. Further, in Sethi, Smith, and Park's [23] research, they found positive impact on product design innovativeness of the inclusion of customers into the product design team, implying the positive impact of multi-perspectives on innovativeness. In the context of an

OSS community, for example, some members simultaneously play the developer and the client roles. This multi-role playing surely enhances positive interactions between clients and developers by reducing communication costs and facilitating the integration of client input into software design. Thus, based on the cross-functional team perspective, it is hypothesized that multi-role playing in an OSS community will increase individual innovativeness.

Social Network/Capital Perspective: Reagans, Zuckerman, and McEvily [20] published a very relevant paper on how internal network density and external network range can positively impact team performance. If those multi-role playing members in an OSS community are treated as forming a virtual cross functional team as discussed above, then they will play a very important role of simultaneously increasing both the internal network density and the external network range for better team performance. First, internal density means the degree to which members of a team share same/similar working experience, knowledge background, and working habits and etc. If the internal density is high, it will enhance mutual identification and trust, enabling social exchanges and coordinated actions that result in more innovative product designs [20]. Second, while members in a cross functional team share a certain role such as the developer role and more easily identify with each other for trust relationship establishment, they may also play other roles

generating links to members with different information, resources, and perspectives, which enhances the team's learning effectiveness and overall creative problem solving capacity. For example, one member plays the site developer and client roles and the other plays the site developer and module developer roles. By linking to other clients and module developers, these two members, as site developers, not only identify with each other, but also bring the client's and module developer's perspectives into their professional discussions and consequently, they may have enhanced learning and improved creative capacity for problem solving. As a result, these team members could generate more innovative ideas to improve the overall OSS development effectiveness for better user experience and increased OSS reliability and scalability [20]. With this theoretical perspective in mind and with the assumption that team performance is the organic aggregation of individual performance, it is hypothesized that multi-role playing will enhance individual's innovativeness.

In summary, based on the above presented community ecological, cross-functional team, and social network perspectives, multi-role playing is hypothesized to be positively related to individual innovativeness in the context of OSS community (Figure 1). The next section is about research method including data collection and empirical test.
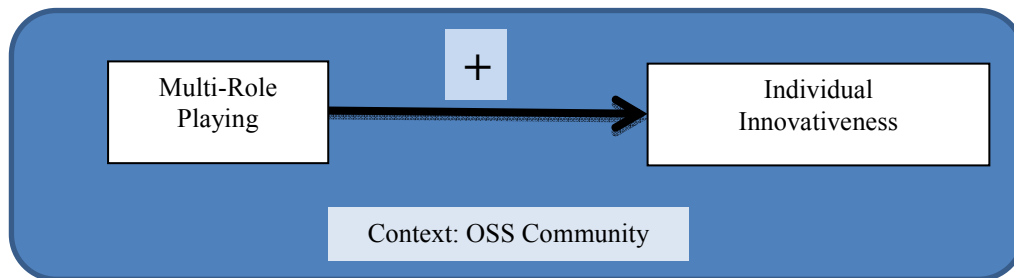

Figure 1: Research Conceptual Model

RESEARCH METHOD

Data Collection

Choice of an OSS Community: OSS Drupal community (www.drupal.org) is chosen as the data source for the empirical test. Drupal is an award winning content management system based on which web systems can be developed to enable e-commerce and digital business. At

the time of writing and revising this paper, based on Drupal community web site, there are 986,195 people in 228 countries speaking 181 languages powering Drupal. Among these people, there are populations such as 28434 module developers and many themers, site developers, educators, and clients forming the eco-system of the Drupal community.
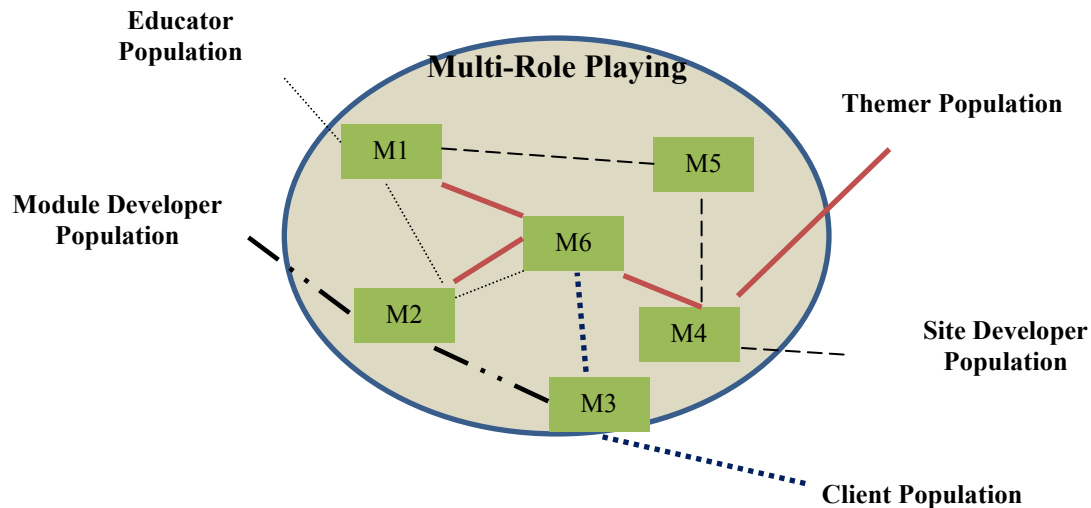
Figure 2: Multi-role Playing in Drupal Community

M1: educator, themer, and site developer; M2: Module developer, educator, and themer
M3: Module developer and client; M4: themer and site developer; M5: site developer; M6: themer, client, and educator

By checking the background of community members' profiles, it is found that some of them do play multi-roles. For example, while some members are module developers, they also use Drupal as the platform to develop web sites for clients (i.e., playing the role of site developers) and write Drupal tutorials and document the Drupal technical details to educate the community (i.e., playing the role of educators). Consequently, this community is an excellent source of data for testing the multi-role playing hypothesis. Figure 2 illustrates the multi-role playing phenomenon in the Drupal community.

Drupal Populations and Their Symbiotic Interactions: As indicated above, the Drupal community consists of quite a few populations including core developers, contributed module developers, themers, site developers, clients, and educators. First, owners of sites developed with the Drupal platform form the Drupal client population. The ultimate value of Drupal should be appraised by these clients. Second, core developers are responsible for designing the overall architecture and its implementation. These developers have the authority to make decisions on whether a contributed module (i.e., the extended functionality of the Drupal platform) can be added to the core and whether it can have a new release. These Drupal core developers are the founder and a few selected members who are critical to the evolution of the Drupal platform. Third, developers of contributed modules are natural extensions of the core developer's population. They should have sol-

id understandings of the overall Drupal architecture and most of the time, they are also key educators of the Drupal system and the major site developers using Drupal and thus, "the number, the degree of commitment, and the level of talents of these members are critical for the Drupal platform to attract more members and build its reputation" [26].

Fourth, themers are those who develop configurable templates and use them to provide customized theming services as a member of a web site development team. The number, quality, and customizability of these theme templates will surely help web layout design to be more interesting and creative. Fifth, site developers are those who understand how to integrate a variety of Drupal elements such as contributed modules and themes to develop customized web sites. Sixth, documentation developers are responsible for writing Drupal technical documents detailing the usage and functions of different technical elements such as modules, themes, and hook mechanisms of extending exiting functionalities in Drupal. These documentation developers can be treated as educators since their work is the foundation for both new and experienced Drupal community members to learn details about how to use the platform more effectively. Besides documentation, educators can also be developers of Drupal tutorial materials (such posting videos on youtube and setting up Drupal camps) and these materials and events helps make the learning of various Drupal elements easier for community

members. These technical documentation and tutorial developers form the Drupal educators' population.

These different populations have symbiotically interdependent relationships from the resource exchange perspective as proposed in [6]. For example, more and well-designed theme templates by themers may attract more site developers to use the Drupal platform to develop web systems due to these templates' positive impact on site stickiness and usefulness. Further, it is natural to believe that site visitors will form their impressions of a web system partially based on the outlook and layout presented through a theme and thus a well-designed library of themes favored by site visitors may help grow the community by transforming casual Drupal site visitors to Drupal system clients. Consequently, the themer population may have positive impacts on the growth of site developer and client populations.

In addition, with more modules coded by the developer population, there is an increasing demand for appropriately placing the functions and information output from those newly developed modules in a web system in such a manner that site visitors can easily recognize and access. Consequently, the demand for themes will increase. Further, while the increasing demand for more customized functions from the client population will naturally demand more output from module developer's and thermer's populations (i.e., market pull), the development of more modules and themes may also attract more clients because of the increased level of comfort clients may feel due to the increasingly powerful Drupal platform and the dependent professional services those module developers and themers are capable of providing. Thus, the development of more modules and themes may very well increase the size of client population (i.e., technology push for market share increase).

Further, with more developed modules and themes, educators are also challenged and motivated to develop documentation and tutorial materials to train new and existing site developers on how to use various Drupal elements. With more educational materials, interested professionals may be transformed into actual site developers, module developers, and themers, and consequently, these populations may grow together accordingly, which may help continuously build the Drupal brand and increase the market share of Drupal in the CMS industry and ultimately grow the Drupal community as a whole. In a nutshell, the Drupal community may grow organically through positive inter-dependent and symbiotic relationships among its populations. And it is believed that the multi-role playing in the context of positive interactions among these different populations in the Drupal community as discussed above provides an excellent source of data for the empirical test of the research hypothesis proposed above.

Drupal Community Member Profiles: Members involved in developing views module (http://drupal.org/project/views) are selected for the test of the multi-role playing hypothesis. The key functions of this views module include 1) facilitating the development of database SQL queries and 2) displaying the retrieved text or multimedia data in a list, a table, or a slideshow, etc. By the time of completing data collection (October 8, 2012), views module was installed on 518,537 sites and downloaded 2,606,167 times and it was the most installed module among 11,194 full projects. The status of views module was also checked recently and it is still the most installed module in Drupal (653901 sites and 4,249,418 downloads on August 21 2013). Due to this fact, it is believed that members who are involved in views module development may represent typical characteristics of Drupal community members and consequently, it is chosen as the data source for the empirical test. There were 143 developers who contributed to the design and constant improvement of views module by the date data collection was completed. The profile data of these members are publically available on-line at http://drupal.org/node/38878/committers. Table 1 lists questions members may respond on their profile page. Information such as name, gender, country of citizenship, and other bio information may also be provided.

Measurement Design

Multi-Role Playing: To measure the degree of multi-role playing by individual members who are involved in developing the views module, four steps are followed. First, the module development involvement score for each member is calculated. Module development involvement is reflected on whether the member is involved in patch contribution to existing modules, new module development, issue queue contribution, project translation, project application review, participation of module test, and development of installation profiles. If one member is involved in one of these activities, he/she will earn one point for module development involvement. The formula used to calculate individual module development involvement score is sum of involvement in the above 7 activities / 7*10. Second, the Individual Theme Design Involvement score is derived by checking one question on the profile page. The formula used is Theme design involvement*10. Theme design involvement score will be 10 if the member is indeed involved with theme development.

Table 1: Profile Questions on Drupal.org

1. I contributed Drupal patches	2. I contributed Drupal modules
3. I contributed Drupal themes	4. I contributed Drupal installation profiles
5. I contributed to Drupal issue queues	6. I contributed Drupal documentation
7. I contributed Drupal translations	8. I contributed Drupal automated tests
9. I reviewed Project applications	10. I help in the Drupal support forums
11. I provide Drupal-related services	12. I give support on IRC
13. I help mentor new contributors	14. Conferences attended

Third, Individual Education Involvement score is calculated by checking whether the member participates forum discussions and Internet Relay Chat (IRC) communications, whether he/she mentors new members, the extent of conference participation (i.e., the number of conference attended/the number of conferences available by the sampling date), and documentation contribution (i.e., each individual's commits/maximal number of commits among members). The formula used is sum of involvement of the above 5 activities/5 *10. Fourth, the individual multi-role playing score is calculated by using the following formula: Module Development Involvement*Theme Development Involvement + Module Development Involvement *Education involvement + Theme Development Involvement *Education involvement.

Individual Innovativeness: this variable is measured through dividing the total number of individual commits by the number of years since she/he registered with the Drupal community web site. Commits represent bug fixes and new feature implementations and they are treated as innovations in the Drupal platform development process in this paper. The intensity of individual innovations (as calculated with the above formula) represents individual innovativeness. This measurement is similar to those success measures in previous studies (e.g., [12]).

Data Analysis

Out of 143 members who are involved in developing views module, males are dominant and occupy 81.81% (117/143) of all the members involved with views module development. USA (27.97%), Germany (9.79%), Canada (5.59%), UK (5.59%), Belgium (4.20%), and Spain (4.20%) are the major participating countries. As to gender, only USA (5) and Canada (1) have female members involved in views module development. Table 2 presents the detailed demographic data. In addition, 60 out of 143 members (42%) who contributed to the views module are Drupal association members and 29 out of these 143 members (20.3%) contributed to theme development. The average amount of time since registration is 264 weeks with a standard deviation of 119.7 weeks.

Tables 3 and 4 present statistics about those members who are involved in various module development and educational activities. Table 4 also shows that the average number of conferences attended by the 96 conference attending members is 4.4 with a standard deviation of 3.4 and the average number of documentation commits for those 97 documentation members is 56.6 with a standard deviation of 157.8.

Table 5 presents individual innovativeness for those who involved in the Views module. The average number of commits to Views module is 49.5 and the average total commits is 671.1 and the average number of projects covered by these members is 31. One observation is that all the standard deviations are much larger than the average, demonstrating that contributions are quite different among members and some of these members can be called as heavy weight contributors while others may be called as light weight contributors.

Table 2: Country Distribution of View Module Developers

Country	Gender				Total	Male Percentage	Country Percentage
	Male	Female	Trans-gender	Not Speci-fied			
US	30	5	2	3	40	75%	27.97%
Germany	14	0	0	0	14	100%	9.79%
Canada	4	1	0	3	8	50%	5.59%
UK	8	0	0	0	8	100%	5.59%
Belgium	6	0	0	0	6	100%	4.20%
Spain	5	0	0	1	6	83%	4.20%
France	5	0	0	0	5	100%	3.50%
Hungary	5	0	0	0	5	100%	3.50%
Netherlands	3	0	0	2	5	60%	3.50%
Other Countries	37	0	0	9	46		32%
Total	**117**	**6**	**2**	**18**	**143**	**82%**	**100%**

Table 3: Module Development Activities and Member Involvement

Module Development Activities	Patches	Module Development	Issue Queue	Transla-tion	Reviewing Project Applications	Automated Test	Installation Profiles
Member Participation	129	108	78	51	24	46	17
Percentage (out of 143)	90.2%	75.5%	54.5%	35.7%	16.8%	32.2%	11.9%

Table 4: Educational Activities and Member Involvement

Education Activities	Forum	Documentation Commits	IRC	Mentoring New Members	Conferences Attendance
Member Participation	55	97	67	18	96
Percentage (out of 143)	38.5%	67.8%	46.9%	12.6%	67.1%
Average (Standard Deviation)		56.6(157.8)			4.4 (3.4)

Table 5: Innovativeness by Individual Members

Innovativeness	Commits to Views Module	Total Commits	Projects Covered
Average	49.5	671.1	31.0
Standard Deviation	336.1	1242.6	52.4

Model Testing

Step-wise regression analysis in SPSS is used to test the impact of multi-role playing on individual innovativeness. The number of projects covered is used as the control variable in the model. This is because with coverage of more projects, a member will have a larger problem space for innovations so that he/she may have more commits than those who do not cover as many projects. Thus, to separate this impact from that of multi-role playing, the number of projects covered variable is used in the regression model as a control variable. In addition, module development, theme development, and education involvement scores are all included for the step-wise regression model initially to test whether they have significant impact on individual innovativeness compared with the multi-role playing variable. All variables are standardized before the regression analysis is implemented.

In Table 6, the R-square (0.392) demonstrates that the regression model explains a significant amount of variance in the individual innovativeness variable by using multi-role playing and the number of project covered

as independent variables. Table 7 shows all the coefficients and demonstrates that multi-role playing indeed significantly and positively impacts individual innovativeness (p-value=0.01). Further, based on tolerance and VIF, no independent variable can be explained a significant amount of its variance by the other independent variables and thus, there is no significant collinearity [14, 1995, page 127].

Step-wise regression analysis is also implemented by giving double weights to documentation commits when calculating individual education involvement score. This is because with better and more complete documentation, members may benefit more from the educational effects of documentation. Tables 8 and 9 present model fit indices, coefficients, and collinearity statistics. These values support the same results as those presented in Tables 6 and 7 with stronger effects (p-value= 0.006). Again, no significant collinearity is found based on tolerance and VIF values. In conclusion, the multi-role playing hypothesis is strongly supported in the context of OSS community.

Table 6: Model Test Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.626	0.392	0.383	0.785

Table 7: Coefficients and Collinearity Test

Model	Standardized Coefficients	t-value	Sig	Tolerance	VIF
(Constant)		-.003	.998		
The Number of Projects Covered	.565	8.396	.000	.958	1.044
Multi-Role Playing Score	.177	2.629	.010	.958	1.044

Table 8: Model Summary
(Documentation Commits Given Double Weight)

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.629	0.396	0.387	0.783

Table 9: Coefficients and Collinearity Test
(Documentation Commits Given Double Weight)

Model	Standardized Coefficients	t-value	Sig	Tolerance	VIF
(Constant)		-0.004	0.997		
The Number of Projects Covered	0.563	8.374	.000	0.957	1.045
Multi-Role Playing	0.188	2.797	.006	0.957	1.045

DISCUSSIONS AND CONCLUSION

Contributions to Research

First, theoretically, the fact that the empirical test strongly supports the multi-role playing hypothesis reinforces perspectives such as community ecological, cross-function team, and social network perspectives in the context of an OSS community with the understanding that team performance is the organic aggregation of individual innovativeness. Second, the fact that all the individual functional involvement variables are excluded from the final step-wise regression model clearly demonstrates the critical and indispensable impact multi-role playing has for individual innovativeness in the connect of an OSS community.

Third, the finding in this paper at the individual level is complementary to the finding in Daniel et al. [7] at the project level. While in their research, the role variety takes two roles (i.e., user and developer) into consideration, the current research incorporates three roles including module developer, themer, and educator roles in the context of Drupal community. With more roles included, this study may capture the degree of role variety in a more comprehensive and refined manner and provide additional evidence on its impact on innovativeness.

Fourth, with the choice of the award winning CMS Drupal community as the source of data, the findings supported by the test may be more demonstrative and representative in the context of OSS community. Thus, built upon existing literature, it is believed that the current study advances our understanding of the factors impacting individual innovativeness in OSS development in an accumulative manner.

Contributions to Practice

As software development is becoming more complicated in terms of technologies used, business processes embedded, and the number of global developers involved, it is clear that a well-organized software development virtual team is becoming increasingly necessary under the OSS development model. The finding in this paper helps OSS development communities learn from successful OSS development and the key lesson here is that OSS development coordinators/organizers/sponsors need to encourage and facilitate multi-role playing in terms of communications and collaboration. Further, managers in commercial settings may also need to take this lesson seriously if they would like to apply the OSS development model.

Research Limitations and Future Research

First, this study used profile data from one module in the Drupal system. Future studies could collect more profile data from multiple modules and the hypothesis could be re-tested and module characteristics may also be included to investigate whether multi-role playing is related to some module specific characteristics such as module size, functional complexity, and the number of members involved [3].

Second, the measurement design for module development, theme development, and education involvement is to count the number of activities members are involved in and in the future, a survey questionnaire could also be used to measure the extent of member involve-

ment in those activities to supplement the measurements in this paper.

Third, the current research does not touch the difference between core developers and contributed module developers. For these two types of developers, multi-role playing may have different impacts on individual innovativeness. While core developers are responsible for the overall architecture design and its implementation, contributed module developers have the focus of extending functions within the existing overall Drupal architecture. A study conducted by Setia, Rajagopalan, Sambamurthy, and Calantone [24] followed this line of thinking and investigated the role of peripheral contributors in enhancing and popularizing an OSS product. Future research could further advance this stream of research by investigating how multi-role playing may differently impact the innovativeness of these two types of developers.

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