GENERATING QUALITY OPEN CONTENT: A FUNCTIONAL GROUP PERSPECTIVE BASED ON THE TIME, INTERACTION, AND PERFORMANCE THEORY[1]

Original Research Article

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Article history:
Received April 1, 2010
Received in revised form June 23, 2010
Received in revised form December 23, 2010
Accepted April 18, 2011

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1 We thank Claudio Vejar and Henry Garcia for their assistance in compiling and computing data for us. This study was partially funded by the Social Sciences and Humanities Research Council of Canada.

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	well as the application of the FLOSS philosophy to the production and distribution of digital information-based products.
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ABSTRACT

We applied the Input-Process-Output approach and Time, Interaction, and Performance theory to examine the input factors (organisational, group-related, and individual) and process factors (group production, group well-being, and member support) that yield group effectiveness, measured as high-quality articles in Wikipedia. The results provided evidence of the positive effects of: group size and shared experience on both group process variables and group effectiveness; group heterogeneity on group production; organisational support and member activeness on group well-being; member activeness on member support; and organisational support and member activeness on group effectiveness.

Keywords: Group research; Input-Process-Output approach; Time, Interaction, and Performance theory; open content; virtual communities; Wikipedia

INTRODUCTION

Open content (OC) has been defined as "content possible for others to improve and redistribute and/or content that is produced without any consideration of immediate financial reward—often collectively within a virtual community." It depends on an alternate philosophical and sociological view of the creation of information products that posits the superiority of open over closed systems, being an extension of open source software (OSS) principles to all domains that pertain to the development of information-based products.

The principles are equally applicable to any discipline that relies on creative intellectual work. As a result, the open source movement has given birth to a broader notion of open content which encompasses any type of creative information-based work, including articles, pictures, audio, or video published under a license that explicitly allows its copying and editing. The original open content license was the GNU Free Documentation License, designed by the Free Software Foundation (FSF) to complement their General Public License (GPL). Other examples of open content initiatives include the MIT's Open Courseware project, the California Open Source Textbook Project, the Harvard University Library Open Collections Program, and a wide spectrum of popular licenses designed by Creative Commons (http://www.creativecommons.org), and Wikipedia, currently the world's largest encyclopaedia. The open source revolution has instigated the emergence of a new philosophy stream that relies on the free nature of any type of information and that emphasizes free collaboration and sharing among human beings acting in virtual communities.

Researchers have tried to understand the OC movement from a descriptive point of view, in terms of ideologies, values, culture and participants' motives [21,35]. While acknowledging the overall success and quality of most OC projects, the 'bazaar-view' of the open source movement leads us to see OC as an obscure environment from which some quality projects arise. But, in fact, such interactions may still be governed by rules and standard group mechanisms among their members, who, in turn, determine the success of the projects.

Our research focused on answering two research questions:

1. **What are the group input factors that contribute to high-quality products in open content practice?**

2. **What are the group process factors that lead to high-quality products in open content practice?**

LITERATURE REVIEW

We explored the open content project quality issue using a group perspective. Recent studies have employed group theory to examine open content projects [7,16]. We focused on group input and group process factors in OC communities by using two theoretical foundations: the Input-Process-Output approach and the Time, Interaction, and Performance theory.

INPUT-PROCESS-OUTPUT MODELS ON GROUP RESEARCH

Input-Process-Output (IPO) models are a direct expression of the functional view of groups; this approach was first introduced in group research in the domain of social psychology. According to IPO models, both the inputs and processes that the groups uses when working together influence the effectiveness of the group; i.e., whether they achieve their production goals, meet members' needs, and maintain themselves over time.

The functional perspective and the general Input-Process-Output model

The *functional perspective* examines groups in terms of the inputs and processes that function to influence group effectiveness [30,34]. This perspective considers group performance as its main focus. It is characterized by the three assumptions [13,14,23,32]: they are goal oriented, their performance varies and can be evaluated, and that internal and external factors influence group performance *via* the interaction process. ***Inputs*** that influence group function include the nature of the task, the internal structure of the group, its cohesiveness, composition, and environment. ***Outputs*** include group effectiveness (productivity, efficiency, and quality), leadership effectiveness, and satisfaction with the outcomes. In IPO models, the inputs have both a direct and indirect effect (by influencing the group process). Inputs include resources such as personnel, task, tools and time [19].

Review of recent MIS studies using an IPO approach

Recent studies investigated the effects of a GSS on the quality of group processes and outcomes [4], the nature of effectiveness within virtual teams [22], and a comparison between face-to-face GDSS and distributed GDSS [3].

An extensive review of processes and outcomes in computer-supported group decision making was conducted by Fjermestad and Hiltz [11]. They integrated 200 different controlled experiments that were discussed in 230 articles. Two of their resulting categories were particularly related to the ***type of group system*** that was used: consensus [15]; and ***usability measures*** due to the use of technology [2]. These did not appear relevant when applied to the performance of OC processes. Another category concerned ***satisfaction measures*** such as participation [28], cohesiveness, conflict management (as an outcome), influence and confidence, all of which are perception-related. Such measures, however, do not capture aspects of group tasks. Finally, the two most studied issues are efficiency and effectiveness measures. Depending on technology and task type, the efficiency measures that have been used are varied. They include decision time, number of decision cycles, number of ideas, time spent in activities, and time spent waiting for a responses.

Effectiveness measures have varied widely in group research. Several approaches have been used: communication, number of comments [10], idea quality, decision quality, decision confidence, process quality, creativity or innovation, level of understanding, task focus, depth of evaluation, and commitment to results.

TIME, INTERACTION, PERFORMANCE (TIP) THEORY

A majority of the reviewed articles used short-term experiments in which groups of participants were formed to perform certain group tasks. This method can ascertain the causal relationships between the independent and dependent variables but omits the temporal dimension of group processes. Because of the overall temporal nature of open content group dynamics and production practices, there was a need to identify additional theoretical considerations that provide a deeper view of the mechanisms involved in group processes.

Group coordination behaviours occur at different levels: by the individual member, among team members, and within the social context. Groups simultaneously perform a number of tasks:

1. **Group production function**: The relation between the group as a functional entity and the environmental conditions and constraints within which a group operates.

2. **Group well-being function:** The activities that are related to the development and maintenance of a group as a system.

3. **Member support function:** The activities related to the ways an individual is embedded within a group.

As MIS group research has often observed artificial groups through laboratory experiments, few studies were found to have drawn insights from the different levels. Using an analogy from the competition between VHS and the Sony Beta videocassette, Dennis and Reinicke [8] argued that brainstorming sessions may not be primarily concerned with the number of ideas generated but may seek group well-being and member support. They developed arguments and empirical evidence that suggested that electronic brainstorming was not as effective as verbal brainstorming in providing group well-being and support.

In conclusion, the social notion of the group is needed in understanding OC practice's overall success. Such a view allows researchers to understand OC processes better by focusing on a level of analysis that will show what factors contribute to OC product quality.

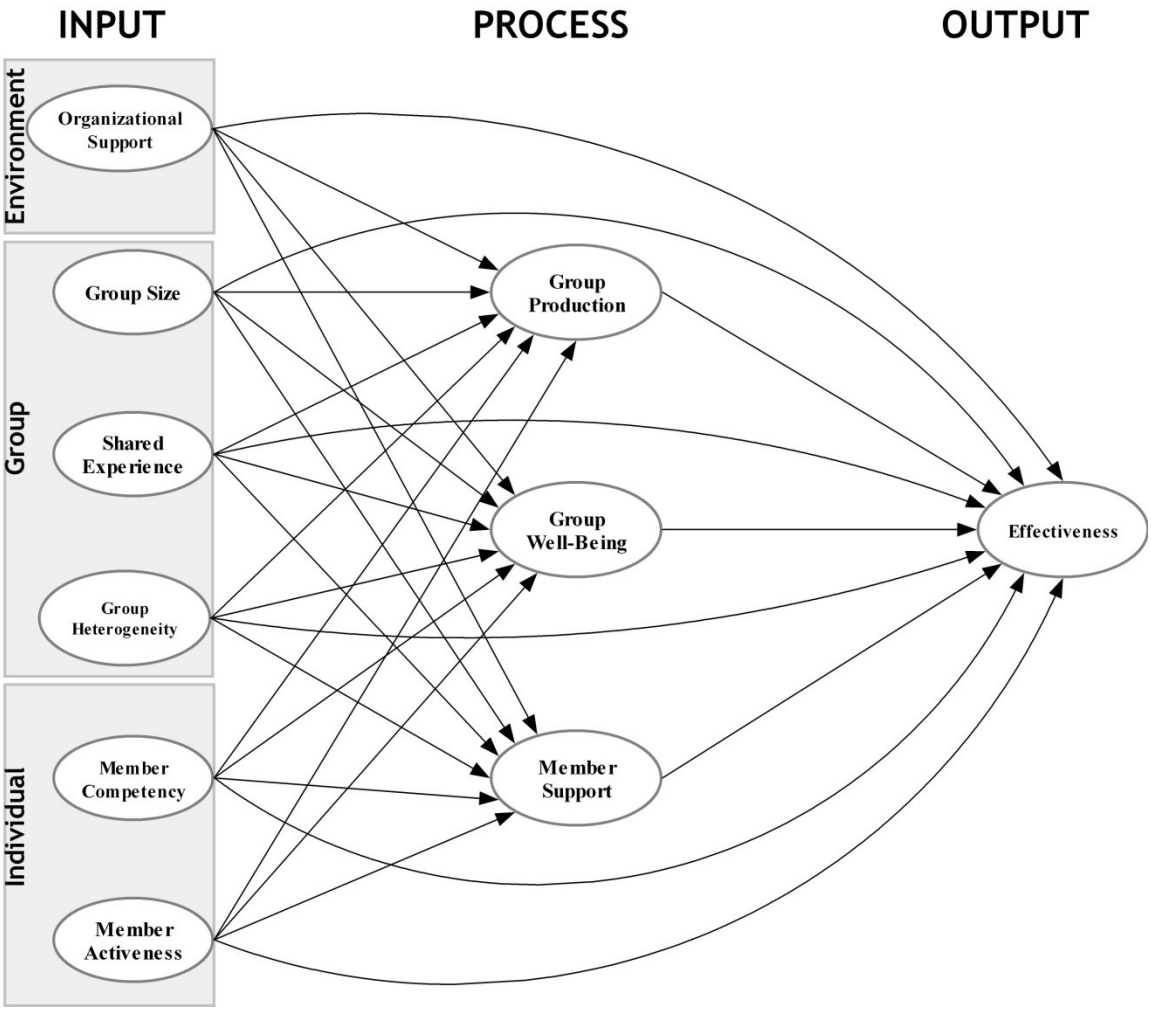

Figure 1: Model of group processes in open content communities

RESEARCH HYPOTHESES

The overall model used in our study is shown in Figure 1. *Group effectiveness* was defined as the extent to which a group is able to perform a certain group task that fulfils a pre-determined list of quality and excellence standards. It was chosen as the primary dependent variable as it is particularly appropriate in solving information-based tasks where quality can be measured through the categorization and specification of quality standards in the OC community.

Input variables

In order to test the relevance of a group research perspective in explaining group effectiveness, we selected the most commonly acknowledged group input variables from our review of the literature. Only those variables that were applicable to open content groups and communities were included. Three main categories of input factors were studied: those that concern the entire group, the individual member, and the organisational factors that consider the context of group work.

Context variables

The management literature has shown that in an organisational context perceived organisational support leads to an increase in employee creativity. Organisational support is defined as an individual's perception that he or she has contributed to the organization in performing a group task. In the OC context, when innovativeness and creativity are prevalent, organisational support seems to play an important role by emphasizing the influence of the OC community on its functions and processes, leading to the hypotheses:

Hypothesis 1a: Organisational support is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.

A meta-analysis of experimental research in the context of GSS and GDSS [5] showed that reward was found to influence group performance through its effect on member motivation, suggesting:

Hypothesis 1b: Organisational support is positively related to group effectiveness.

Group composition variables

These characterize groups as discrete entities. Three variables were included in the model: group size, shared experience, and group heterogeneity.

Group size

This is measured as the number of people who have contributed to achieving a specific group task. Prior studies have shown that a minimum group size of about eight is necessary for successful use of a GSS. Moreover, it was also found that group size may be an important moderator when measuring decision time and satisfaction with the process, with decision time being shorter and satisfaction higher for larger groups.

Nonetheless, group research has found conflicting results about the influence of group size on group performance. For instance, Ridings and Wasko [31] highlighted a paradox: in large groups, the amount of communication activity increases to a point where the sustainability of the group becomes questionable. This then creates an information overload in which the number or length of messages becomes too high to process, negatively influencing a group performance and outcome.

Similarly, some GSS studies found that large groups tend to become less mutually aware and thus less effective [33]. In this study, we decided to adopt the majority view that sees group size as positively

influencing group processes and performance. Therefore, we hypothesized:

Hypothesis 2a: Group size is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.

A study of electronic meeting systems (EMS), using two concurrent experiments with groups of varying sizes, analysed the number and quality of unique ideas generated by groups of each size using electronic and non-electronic verbal brainstorming. Larger groups were found to generate more unique and high-quality ideas, and members were more satisfied with the EMS.

Hypothesis 2b: Group size is positively related to group effectiveness.

Shared experience

This is the extent to which the group members have previously collaborated in group projects. We posited that this was an important factor in explaining group processes:

Hypothesis 3a: Shared experience is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.

In Fjermestad and Hiltz's study, 25 articles were found to use group composition variables as independent variables. They found that only eleven articles (out of 200) used groups that had been established before the study, whereas the rest used groups formed only for the experiment, mainly of college students. As a result, there was little investigation of shared experience effects, leading to:

Hypothesis 3b: Shared experience is positively related to group effectiveness.

Group heterogeneity

This is defined as the extent to which group members have varying characteristics (the diversity of group activity, personality traits, attitudes, backgrounds, and abilities). In a study that explored the relationship between group heterogeneity, group rewards, and successful participation in system development, Aladwani et al [27] both group heterogeneity and group-based rewards were found to impact participation. However, some past findings provided an alternative view in which group heterogeneity lead to negative consequences. For instance, in a study about the impact of the use of a GSS for group conflict resolution, though group heterogeneity provided a wider range of ideas and experiences, Miranda and Bostrom [27] found to generate more conflict and the management of the group was likely to be more difficult. Similarly, Paul et al. [1] indicated that a high level of heterogeneity in a group could lead to an increase in group conflicts and communication challenges. We decided to follow the more dominant perspective, which considered that group heterogeneity had a positive impact:

Hypothesis 4a: Group heterogeneity is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.

Heterogeneous groups may enjoy a wider base of experiences, skills, abilities, and perspectives that can help groups to be more effective in group tasks. It has been demonstrated that group heterogeneity can lead to performance gains by improving the quality of the decision strategies employed by workgroups. Such diversity in membership expands the resources available, thereby increasing the likelihood of improved productivity. Therefore:

Hypothesis 4b: Group heterogeneity is positively related to group effectiveness.

Member characteristics: Competency and activeness

Member characteristics potentially include attributes of individual members such as their attitudes, personality traits, age, or previous experience with systems and tasks, as well as activeness in the community. Fjermestad and Hiltz concluded that both job tenure and member experience (the extent to which an individual has participated in group projects in an organization) had been effectively considered in GSS research. Member tenure is the time spent by an individual in an organization or community. Furthermore, it was found that that the amount of experience and training, amount of external

versus internal facilitation, and use of GSS all correlated with multiple aspects of pre-meeting planning and agenda use. Member experience can also be associated with members' tenure in an organization. We posited that, in a virtual community, member experience may be categorized in terms of position nomination, such as administrative positions or peer recognition seen as a direct consequence of experience.

It is thus apparent that the member experience issue encompasses broad and varied notions, deserving further sub-categorization. In our study, we distinguished between two general categories of member experiences. Member competency (characteristics that describe a member's innate skills, capabilities, knowledge and roles that may be valuable in fulfilling group tasks) is distinct from member activeness, which refers to the extent to which a member has actively participated in group tasks in the organization. The following hypotheses were thus formulated:

Hypothesis 5a: Member competency is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.

Hypothesis 6a: Member activeness is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.

Benbasat and Lim's review of GSS research suggested that the presence of a leader exercising appropriate influence could improve group performance, and that, conversely, a lack of leadership could have negative effects, leading to:

Hypothesis 5b: Member competency is positively related to group effectiveness.

Hypothesis 6b: Member activeness is positively related to group effectiveness.

Group process variables

Group production function

Group production refers to the set of activities, seen as a functional entity, that a group performs to work on a common task. The group production function is the system in which task performance occurs. Groups are thus seen as functional units whose output is a task that is effectively performed.

Several aspects of the function have been investigated in past studies. Fjermestad and Hiltz identified six studies that investigated participation equality as a process variable, whereas a seventh focused on level of effort. In another review intended to show the differences between electronically-supported GDSS and face-to-face meetings, equality of participation did not differ. A longitudinal study that compared the developmental patterns of groups in three different electronically-supported modes (face-to-face, dispersed asynchronous, and dispersed-synchronous) found no particular difference among the three modes [6]. Furthermore, another project found that greater inhibition occurs in face-to-face groups leading to the potential for less equality of participation than in distributed EMS groups while more equal participation was observed [20]. As a consequence:

Hypothesis 7: Group production is positively related to group effectiveness.

Group Well-being function

This describes the activities that deal with the development and maintenance of a group whose well-being consists of all actions that make contributions to the group as a distinct and continuing social structure.

Past research has studied several aspects of the group well-being function. Communication behaviour has been explored [24]. Fjermestad and Hiltz also found twelve studies that addressed communication as a process variable. They also found seven articles about information exchange, three about information credibility and ten about information sharing.

Other group well-being issues, such as coordination, have been identified. In a research project that examined the effect of system restrictiveness of coordination structures in an asynchronous environment, it was concluded that groups with parallel coordination mode have a stronger belief that the decisions they made are of higher quality than those of groups with sequential coordination mode [18]. A study that explored the effects of temporal coordination on virtual teams in the context of Lotus Notes showed through an experiment that coordination had a moderating effect on group outcomes [25].

Group conflicts have raised many problems in practice, because of cultural differences among group members and team heterogeneity in general [26]. Conflicts are part of the group well-being function as it characterizes a certain type of group member interaction. Group conflict was studied in an investigation of cognitive conflicts associated with the use of level 1 and level 2 GDSSs [9]. The results suggested that GDSSs reduced disagreement between group members and improved consistency of judgment better than other meeting environments. From this, we hypothesized:

Hypothesis 8: Group well-being is positively related to group effectiveness.

Member support function

This refers to the activities that deal with ways that the individual is embedded in the group; it describes the relations between individual members and the group. The lack of both temporal and contextual considerations in group research has somehow caused member support issues to be neglected. The member support function concerns all process issues that are related to member compensation, payback, and relationship building. Compensation and payback considerations may concern either direct rewards or any knowledge or skills that an individual member may gain through group work.

A study of the way in which leaders developed relationships with their virtual team members found that they considered it essential to build some level of personal relationship with their members before starting working together [29]. As a consequence:

Hypothesis 9: Member support is positively related to group effectiveness.

METHODOLOGY

Group research has been criticized in its recurring preference for lab experiments and the artificial nature of the tasks assigned to the groups. In response to these concerns, a quantitative field study of a virtual community appeared to be most appropriate for our study. First, it studied groups in their native context: a real OC community in their normal context. Second, it considered tasks that were already known and natural to groups, thus minimizing bias in the results. Indeed, the focus of this research was to study the overall behaviour of groups that were driven by an open content philosophy and culture.

RESEARCH SAMPLE

To test the model, we investigated the group interactions of Wikipedia (http://en.wikipedia.org), the world's largest open content community. As of May 2011, it contained over 18 million articles written in over 250 languages; over 3.6 million articles were in English. Wikipedia's policy is that its contributors must adopt a neutral point of view and include only well-documented facts in an article. Quality control is carried out through peer review by over 24 million contributors.

We focused only on the English portion of Wikipedia, using the entire English database as of April 21, 2005. This was the most recent version available that contained the full editing history, including all changes made in the Wikipedia database since its foundation in 2001 and was computationally feasible for us. (Note that this should not be confused with the much smaller set of

current articles, which would be insufficient for our purposes. As of April 2011, the compressed size of the English Wikipedia was 6.7 GB.) It allowed us to analyse the interactions between the contributors in our sample. At that time, Wikipedia contained a total of 545,486 articles but due to computing and memory limitations, a sampling decision was made to select only 10,000 for analysis.

A so-called ***featured*** article is a particularly well-written and complete Wikipedia article that meets several key quality criteria: it must be comprehensive, accurate, stable, well-written, neutral in its stance, factually accurate, in compliance with Wikipedia's style standards, contain relevant pictures, and be of an appropriate length. At the time of our data collection, 1 in 900 articles met this standard.

On the date of the sample download, there were 580 featured articles; in addition there were 497 articles that had been nominated for featured status but had been rejected.

Only articles larger than 5,000 characters (approximately 833 words) were selected as members of our sample—the shortest was 5,601 characters long. All featured articles were included in the sample, as were all articles of minimum size nominated for featured status but rejected. In addition, a random sample of 8,923 other articles was selected, to give a sample of exactly 10,000 articles for the study. The sample was characterized by an average article length of 12,653 characters (σ=12,298) and an average group size of 28 contributors (σ=41).

In addition to the 10,000 selected articles, the corresponding "talk" pages were also downloaded. *Talk pages* allow contributors to interact, discuss, and debate issues in direct relation to the article itself. Furthermore, the "user" pages and "user talk" pages of all the users having contributed at least once in one of the 10,000 articles were downloaded. User pages are contributors' personal home pages in the community, and their auxiliary user talk pages are used to maintain personal discussions with other contributors.

OPERATIONALIZATIONS AND MEASUREMENT

The Output variable

The effectiveness of the article involves an assessment of its overall quality. To measure this, we devised a scoring system based on the article's status in the community: if it had been elected by the community as a "featured" article it was scored by giving its Output Variable a value of "2". On the date of the sample download, there were 580 featured articles. In addition, as of that date, there were 497 articles that had been nominated for featured status but had been rejected; these we scored by giving their output variable a value of "1". All other articles in the database were given a score of "0".

Input and process variables

Several of our theoretical constructs were measured as reflexive variables, where the variation in the scores on measures of a construct was considered to be a function of the true score of the construct plus an error term [17]. Shared experience, member competency and member support were measured with items that are expected to covary, thus needing a reflective approach. Furthermore, group size and effectiveness were treated as reflective constructs: they were operationalized as single-indicator constructs.

Other constructs were measured as formative variables, for which the direction of causality should be viewed as emanating from the measures to the corresponding construct [17]. Organisational support, group heterogeneity, activeness, production, and well-being were conceptualized as formative

constructs. The operationalization and measurement of the constructs are summarized in Table 1.

To capture the multi-dimensional nature of both group heterogeneity and member activeness, we operationalized the constructs using the categorization of group processes. For instance, a member may be extremely active in terms of task-related production (group production) but may not interact at all with other members (group well-being and member support functions). It is important to note that the scores of group heterogeneity and member activeness in terms of group production, group well-being, and member support were computed based on the total number of contributions of each member in the entire Wikipedia database. Such scores were thus not related to the group process scores, which were computed for each article of the sample.

DATA ANALYSIS AND RESULTS

We developed a group model that relies on group input, process, and output, and tested it using partial least squares (PLS) analysis; this permits the testing of multi-level models that feature interactions and multiple-cause effects. Moreover, PLS can handle both reflective and formative constructs, which made it the most appropriate statistical tool for our study. After having verified the adequacy of the constructs and the robustness of the measures, we assessed the structural model by estimating the path coefficients, which indicated the strength of the relationship between independent and dependent variables in testing the hypotheses, and the validity of the model by examining R^2 and the structural paths.

Table 1: Constructs operationalization and measurement

	Variable Name	Operationalization	Measure Name	Measurement
INPUT	Organisational Support (formative)	Collaboration of the week/ Article Improvement Drive/ Requests for Expansion/ Pages Needing Attention/ Cleanup Requests	in_orgsup_sum	The total number of times an article received formal visibility and an official call for contribution through one or more of the following official Wikipedia designations: "collaboration of the week"; "improvement drive"; "page needing attention"; "request for expansion" request; or "cleanup" request.
		Peer Review	in_orgsup_peerrev	The total number of times an article received a "peer review" request.
	Group Size	Open-Group Size	in_size_open	The total number of contributors of an article.
	Shared Experience (reflective)	Article Shared Experience	in_shexp_art	The number of times that pairs of contributors of the article interacted in the article itself divided by group size.
		Discussion Shared Experience	in_shexp_talk	The number of times that pairs of contributors of the article has interacted in the article talk page divided by group size.

Variable Name	Operationalization	Measure Name	Measurement
Group Heterogeneity (formative)	Tenure Heterogeneity	in_tenurstd	The standard deviation of Member Tenure.
	Group Production Heterogeneity	in_membprodstd_contsize	Member Contribution Size Heterogeneity: The standard deviation among group members of the average size of contributions per user.
		in_membprodstd_contfreq	Member Contribution Frequency Heterogeneity: The standard deviation among group members of the average number of contributions per day per user.
	Group Well-Being Heterogeneity	in_gpwellstd_comsize	Member Comment Size Heterogeneity: the standard deviation among group members of the average size of comments per user in article talk pages.
		in_gpwellstd_comfreq	Member Comment Frequency Heterogeneity: the standard deviation among group members of the average number of comments per day per user in article talk pages.
	Member Support Heterogeneity	in_membsupstd_comsize	Member User Comment Size Heterogeneity: the standard deviation among group members of the average size of comments per user in other users' user pages and user talk pages (i.e., on users' personal profile pages).
		in_membsupstd_comfreq	Member User Comment Frequency Heterogeneity: the standard deviation among group members of the average number of comments per day per user in other users' user pages and user talk pages;
Member Competency (reflective)	Average Member Tenure	in_tenuravg	A contributor's length of experience in the Wikipedia community, measured as the number of days since their first contribution.
	Presence of Administrators	in_admin	The number of administrators (members elected by other members as experienced and responsible) that have contributed of the article divided by the total number of contributors of the article.

	Variable Name	Operationalization	Measure Name	Measurement
		Peer Recognition	in_peerrec_barn	The total number of barnstars attributed to the contributors of the article divided by the total number of contributors of the article.
			in_peerrec_awd	The total number of awards (wikithanks) attributed to the contributors of the article divided by the total number of contributors of the article.
	Member Activeness (formative)	Group Production Activeness	in_membprodavg_contsize	The average among group members of the average size of contributions per user.
			in_membprodavg_contfreq	The average among group members of the average number of contributions per day per user.
		Group Well-Being Activeness	in_gpwellavg_comsize	The average among group members of the average size of comments per user in article talk pages.
			in_gpwellavg_comfreq	The average among group members of the average number of comments per day per user in talk pages.
		Member Support Activeness	in_membsupavg_comsize	The average among group members of the average size of comments per user in other users' user pages and user talk pages.
			in_membsupavg_comfreq	The average among group members of the average number of comments per day per user in other users' user pages and user talk pages.
PROCESS	Group Production (formative)	Participation Equality	pr_partic_contsizestd	The standard deviation of the total size of contributions per contributor of the article
			pr_partic_contnbstd	The standard deviation of the number of contributions per contributors of the article.

Variable Name	Operationalization	Measure Name	Measurement
		pr_effort_totsize	Total size of the article in number of characters.
	Effort Level	pr_effort_contnb	The total number of contributions to the article.
		pr_effort_contavgsize	The average size of the contributions to the article by all contributors.
	Production Rate	pr_prodpat_artage	Production process length: The amount of time, in days, that has passed from the date of the first contribution.
		pr_prodpat_sizerate	Average size of contributions per day.
		pr_prodpat_rate	Production Speed: Average number of contributions per day.
		pr_prodpat_regul	Production Regularity: Standard deviation of the number of contributions per month.
	Emergent Leader	pr_lead_deg	Emergent Leader's Degree of Participation: The % number of edits of the user who has posted more contributions to the actual article than any other contributor.
		pr_lead_size	Emergent Leader's Size of Participation: The % size of total contributions of the user who has posted more contributions to the actual article than any other contributor.

Variable Name	Operationalization	Measure Name	Measurement
Group Well-Being (formative)	Information Exchange	pr_infoex_talksize	Length of the talk page.
		pr_infoex_comavgsize	Average size of a comment in a talk page.
	Interaction Degree	pr_interac_avgcomusr	The % group members (contributors of the article) who have participated in the talk page.
		pr_interac_membperc	The average number of comments per user.
		pr_interac_comnb	The number of comments in the talk page.
	Coordination	pr_coord	The number of "to-do" tasks found in the entire history of the article talk page.
	Level of Conflict	pr_confl_sum	The number of times an article has been quoted in “NPOV", "request for comments page", and other pages that document conflicts between contributors.
	Emergent Facilitator	pr_facil_deg	Emergent Facilitator’s Degree of Participation: The % number of comments of the user who has posted more comments to the article talk page than any other contributor.
		pr_facil_size	Emergent Facilitator’s Size of Participation: The % size of total comments of the user who has posted more comments to the article talk page than any other contributor.
Member Support (reflective)	Relationship Building	pr_relbuild_nb	The number of comments that a contributor has received on his per her user page and user talk page from the other contributors of the considered article divided by the total number of contributors of the article.

	Variable Name	Operationalization	Measure Name	Measurement
			pr_relbuild_size	The total size of the comments that a contributor has received on his per her user page and user talk page from the other contributors of the considered article divided by the total number of contributors of the article.
OUTPUT	Effectiveness	Article Quality	feat_nom_score	Article quality level among: regular article with no nomination, featured article nominees that were not accepted, and featured articles.

ASSESSMENT OF THE MEASUREMENT MODEL (OUTER MODEL)

To validate the measurement model, a distinction had to be made between reflective and formative constructs. The traditional method used for assessing both construct reliability and validity are not appropriate for formative constructs, where the direction of causality is posited to flow from the measures to the constructs.

Following the procedures used in prior analysis using PLS, the adequacy of the reflective constructs was assessed through the following tests: item reliability, construct reliability, convergent validity, and discriminant validity. The formative constructs were validated by looking at item collinearity and discriminant validity. In PLS, both reliability and validity tests of a measurement model were assessed through the use of confirmatory factor analysis. The results of the analysis are presented in Tables 2 and 3.

Table 2: Confirmatory Factor Analysis (CFA) results for the reflective constructs

Construct	Item	Initial instrument		Refined instrument		
		Weights	Loadings	Weights	Loadings	p-value
Shared Experience	in_shexp_art	0.502	0.867	0.539	0.882	0.000
	in_shexp_talk	0.618	0.914	0.583	0.900	0.000
Member Competency	in_tenuravg	0.598	0.840	0.780	0.958***	0.000
	in_admin	0.356	0.808	0.335	0.755***	0.000
	in_peerrec_barn	0.200	0.441			
	in_peerrec_awd	0.246	0.496			
Member Support	pr_relbuild_nb	0.566	0.957	0.566	0.961***	0.000
	pr_relbuild_size	0.487	0.941	0.487	0.945***	0.000

$*p \leq 0.05$; $**p \leq 0.01$; $***p \leq 0.001$

Table 3: Correlation between latent constructs (square root of AVE in the leading diagonal)

	Composite Reliability (ρ)	AVE	Group Size	Shared Exp	Member Comp	Member Support	Effectiveness
Group Size	N/A	1.000	1.000				
Shared Experience	0.886	0.795	0.517	0.892			
Member Competency	0.851	0.743	0.129	0.458	0.862		
Member Support	0.948	0.900	0.492	0.557	0.281	0.949	
Effectiveness	N/A	1.000	0.422	0.434	0.050	0.303	1.000

Reflective latent variables

Item reliability verifies whether each of the measurement items acts consistently as a measure of its corresponding construct. In PLS, individual item reliability for reflective latent variables is assessed by examining the loadings of the measures with their respective construct (by CFA), with a minimum acceptable loading of 0.7. Among the reflective constructs, two items had loadings below 0.7 and were dropped. The p-values were found in deriving them from the corresponding t-values obtained after having run a bootstrap procedure with 200 resamples.

Construct reliability was assessed using composite reliability (ρ), whose minimum should be 0.8, and average variance extracted (AVE), which should be at least 0.5. There were satisfactory values of both ρ and AVE.

All item loadings in the final instrument were above 0.7 ($p < 0.001$), thus confirming high construct validity. Discriminant validity was tested according to the two methods recommended by Gefen and Straub [12]. The first step was to verify that all items scored highly on their assigned factor but not on others. The results of this cross-loading analysis are shown in Table 4. All items scored much higher for their latent variables. Second, the square root of every AVE should be higher than the correlation coefficients of any pair of the latent constructs. The square root AVE of all reflective latent constructs was consistently higher.

Table 4: Cross-loadings

Reflective variables	Formative Variables									
	Group Size	Shared Exp	Memb. Comp	Memb. Sup	Effect.	Org Sup	Group Heter.	Memb. Activ	Group Prod	Group Well
in_size_open	**1.0**								0.693	
in_shexp_art		**0.882**							0.633	
in_shexp_talk		**0.900**							0.515	

in_tenuravg		0.469	**0.959**								
in_admin		0.277	**0.752**								
pr_relbuild_nb		0.572		**0.957**							
pr_relbuild_size		0.478		**0.941**							
feat_nom_score		0.434			**1.0**						
in_orgsup_sum						**0.190**					0.0995
in_orgsup_peerrev						**0.990**					0.291
in_tenurstd			0.581				**0.790**				
in_membprodstd_contsize							**0.342**		0.206		
in_membprodstd_contfreq		0.320					**0.344**				
in_gpwellstd_comsize							**0.379**		0.218		
in_gpwellstd_comfreq							**0.669**	0.687			
in_membsupstd_comsize				0.133			**0.105**				
in_membsupstd_comfreq							**0.561**	0.422			
in_membprodavg_contsize		-0.0612	-0.0864				0.0575	**-0.0543**	-0.0912		
in_membprodavg_contfreq	-0.154							**-0.149**			
in_gpwellavg_comsize							0.212	**0.276**			
in_gpwellavg_comfreq							0.433	**0.813**			
in_membsupavg_comsize				0.109				**0.0742**			

in_membsupavg_comfreq						0.246	**0.435**	
pr_partic_contnbstd				0.320				**0.320**
pr_effort_totsize	0.414							**0.547**
pr_effort_contavgsize						-0.180		**-0.160**
pr_prodpat_artage		0.625						**0.790**
pr_prodpat_sizerate			-0.148			-0.162		**-0.138**
pr_prodpat_rate	0.220							**0.190**
pr_prodpat_regul	0.379							**0.357**
pr_lead_deg						-0.480		**-0.563**
pr_lead_size	0.172							**0.216**
pr_infoex_talksize	0.518							**0.859**
pr_infoex_comavgsize							0.286	**0.468**
pr_interac_avgcomusr							0.319	**0.556**
pr_interac_membperc							0.249	**0.529**
pr_coord				0.157				**0.314**
pr_confl_sum	0.281							**0.513**
pr_facil_size							0.0477	**0.0662**

When the highest correlation factor of an indicator is inside its corresponding construct, the second highest correlation factor is displayed. In case the highest correlation factor of an indicator is not inside its corresponding construct, then all the correlation factors that are also higher are displayed.

Formative latent variables

Item collinearity and discriminant validity were next examined. Because the formative measurement model was based on multiple regression, the stability of the indicator coefficients could be strongly affected by a strong inter-correlation between the items of a same construct. For each formative construct, the Variance Inflation Factor (VIF) was computed. These measure the impact of collinearity among the independent variables in a regression model on the precision of estimation. The model expresses the degree to which collinearity among the predictors degrades the precision of an estimate.

The literature has used several common cut-off points ranging from 10 to 2.5. We decided that all the items whose VIF value was above 2.5 had to be removed from the measurement instrument. Second, discriminant validity was assessed by using a cross-loading analysis.

As a result of the assessment of the formative constructs of the measurement model, out of the 34 formative indicators, two were dropped for multi-collinearity reasons and two more were dropped for discriminant validity issues, resulting in refined formative construct measures and a fully validated measurement instrument. Table 5 shows the weights of the items in each formative construct before and after refinement.

Table 5: Confirmatory Factor Analysis (CFA) results for the formative constructs

Construct	Item	Initial instrument	Refined instrument				
			Weights	Loadings	Weights	Loadings	p-value
Org. Support	in_orgsup_sum	0.157	0.203	0.145***	0.190	0.000
	in_orgsup_peerrev	0.980	0.988	0.983***	0.990	0.000
Group Heterogeneity	in_tenurstd	0.468	0.681	0.607***	0.778	0.000
	in_membprodstd_contsize	0.280	0.391	0.233***	0.360	0.000
	in_membprodstd_contfreq	-0.028	0.310	0.026	0.339	0.122
	in_gpwellstd_comsize	0.251	0.433	0.197***	0.387	0.000
	in_gpwellstd_comfreq	0.469	0.728	0.375***	0.670	0.000
	in_membsupstd_comsize	0.104	0.126	0.075***	0.104	0.000
	in_membsupstd_comfreq	0.196	0.601	0.176***	0.561	0.000
Member Activeness	In_membprodavg_contsize	-0.007	0.025	-0.086*	-0.046	0.017
	in_membprodavg_contfreq	-0.579	-0.124	-0.597***	-0.155	0.000
	in_gpwellavg_comsize	0.171	0.283	0.179**	0.286	0.003
	in_gpwellavg_comfreq	1.01	0.823	1.04***	0.803	0.000
	in_membsupavg_comsize	0.165	0.112	0.129***	0.076	0.000
	in_membsupavg_comfreq	0.065	0.484	0.005	0.428	0.471
Group Production	pr_partic_contsizestd	-0.118	0.301			
	pr_partic_contnbstd	-0.042	0.296	0.236***	0.332	0.000
	pr_effort_totsize	0.247	0.525	0.373***	0.549	0.000
	pr_effort_contnb	0.807	0.934			
	pr_effort_contavgsize	-0.030	-0.081	-0.083***	-0.155	0.000
	pr_prodpat_artage	0.235	0.573	0.563***	0.771	0.000
	pr_prodpat_sizerate	-0.022	-0.072	-0.063**	-0.134	0.005
	pr_prodpat_rate	0.028	0.243	0.070***	0.201	0.000
	pr_prodpat_regul	-0.066	0.406	0.150*	0.408	0.039
	pr_lead_deg	-0.068	-0.390	-0.274***	-0.549	0.000
	pr_lead_size	0.097	0.198	0.144**	0.253	0.004
Group Well-Being	pr_infoex_talksize	-0.140	0.765	0.735***	0.860	0.000
	pr_infoex_comavgsize	0.196	0.388	0.178***	0.458	0.000
	pr_interac_avgcomusr	0.386	0.428	0.404***	0.543	0.000
	pr_interac_membperc	-0.414	0.417	-0.162	0.520	0.087
	pr_interac_comnb	1.08	0.909			

		pr_coord	0.151	0.264	0.229***	0.306	0.000
		pr_confl_sum	0.050	0.438	0.145**	0.498	0.003
	pr_facil_deg	-0.105	0.034				
		pr_facil_size	0.005	0.048	0.002	0.088	0.446

ASSESSMENT OF THE STRUCTURAL MODEL (INNER MODEL)

PLS Graph 3.00 was used in assessing the structural model. This test consisted of estimating the path coefficients indicating the strength of the relationship between independent and dependent variables in order to test the hypotheses. The R^2 for each endogenous construct in the theoretical model corresponded to the amount of variance explained by independent variables. These values were interpreted similarly to the R^2 provided by the regression model. Because PLS does not generate an overall goodness-of-fit index, the validity of a model was assessed by examining R^2 and the structural paths. To acknowledge possible weak relationships, we took note of path coefficients between 0.1 and 0.2.

All the exogenous variables explained 66% of the variation in group production, 35.7% of the variation of group well-being, and 38% of the variation of member support. Overall, 29% of the variation of the primary dependent variable, effectiveness was explained by the variables of the model. The significance of the R^2 coefficients was determined using an *F*-test. Every R^2 was found to be significant at the 0.001 level. The detailed hypothesis results are summarized in Table 6. Figure 2 and Table 7 present the overall findings.

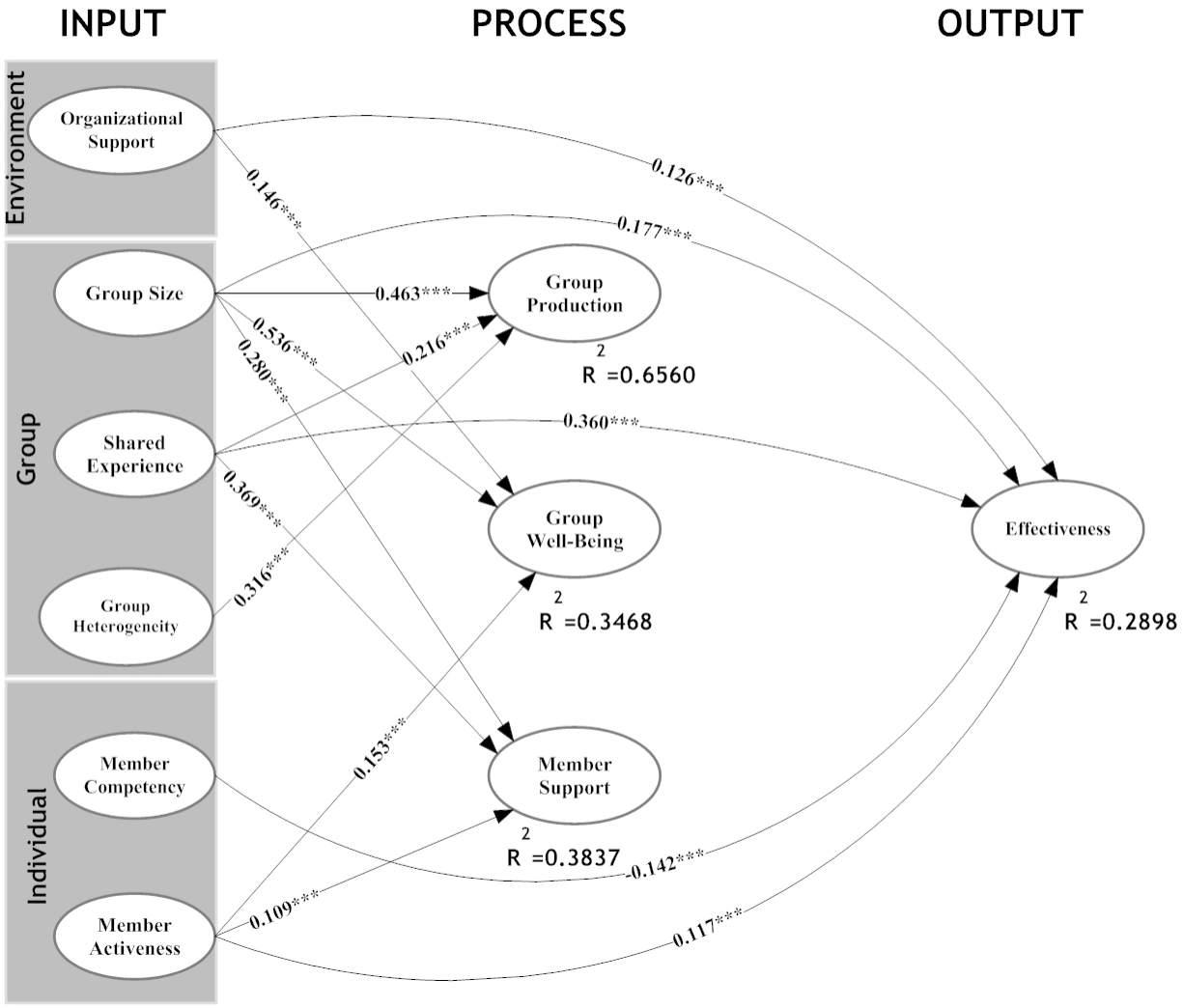

Figure 2: Verified paths in model of group processes in open content communities

DISCUSSION AND IMPLICATIONS OF RESULTS

PREDICTIVE ABILITY OF OPEN CONTENT GROUP INPUTS

Organisational support was shown to be positively related to group well-being (path of 0.146, $p < 0.001$) in Wikipedia operations. Its organisational support is expressed through peer review requests, where people are encouraged to join the group in charge of updating an article to discuss how it could be modified and improved. However, group production was not found to be affected by organisational support. Thus it seems that organisational support for open content groups plays a role in stimulating their

social activities by increasing discussion, coordination, and information exchange but not the production task. Furthermore, members are influenced by organisational support in group activities that are only directly related to their group task.

Table 6: Path coefficients and R^2 for overall model

Predictor Construct	Predicted Construct	Path	t-value	p-value	Hypothesis
Organisational Support	→ Group Production	0.022	1.443	0.075	$H_{1a(i)}$
	→ Group Well-Being	**0.146*****	5.831	0.000	**$H_{1a(ii)}$**
	→ Member Support	0.045***	3.734	0.000	$H_{1a(iii)}$
	→ Effectiveness	**0.126*****	7.351	0.000	H_{1b}
Group Size	→ Group Production	**0.463*****	11.844	0.000	**$H_{2a(i)}$**
	→ Group Well-Being	**0.536*****	5.857	0.000	**$H_{2a(ii)}$**
	→ Member Support	**0.280*****	16.135	0.000	**$H_{2a(iii)}$**
	→ Effectiveness	**0.177*****	5.845	0.000	**H_{2b}**
Shared Experience	→ Group Production	**0.216*****	11.908	0.000	**$H_{3a(i)}$**
	→ Group Well-Being	-0.072	1.469	0.071	$H_{3a(ii)}$
	→ Member Support	**0.369*****	21.559	0.000	**$H_{3a(iii)}$**
	→ Effectiveness	**0.360*****	15.801	0.000	**H_{3b}**
Group Heterogeneity	→ Group Production	**0.316*****	11.936	0.000	**$H_{4a(i)}$**
	→ Group Well-Being	-0.017	0.751	0.226	$H_{4a(ii)}$
	→ Member Support	-0.033**	2.643	0.004	$H_{4a(iii)}$
	→ Effectiveness	-0.073***	4.927	0.000	H_{4b}
Member Competency	→ Group Production	0.055***	5.747	0.000	$H_{5a(i)}$
	→ Group Well-Being	-0.031	1.380	0.084	$H_{5a(ii)}$
	→ Member Support	0.077***	8.101	0.000	$H_{5a(iii)}$
	→ Effectiveness	**-0.142*****	15.990	0.000	H_{5b}
Member Activeness	→ Group Production	-0.095***	5.707	0.000	$H_{6a(i)}$
	→ Group Well-Being	**0.153*****	5.428	0.000	**$H_{6a(ii)}$**
	→ Member Support	**0.109*****	6.053	0.000	**$H_{6a(iii)}$**
	→ Effectiveness	**0.117*****	9.323	0.000	**H_{6b}**
Group Production	→ Effectiveness	0.075*	2.252	0.012	H_7
Group Well-Being	→ Effectiveness	0.014	0.441	0.330	H_8
Member Support	→ Effectiveness	-0.002	0.139	0.445	H_9

(In **bold**: significant paths ($p \leq 0.05$) whose value equals or exceeds 0.1).

R^2	F-value	p-value		
Group Production	0.656***	2116.744	0.000	
Group Well-Being	0.347***	757.857	0.000	***p ≤ 0.050**
Member Support	0.387***	3111.998	0.000	**** p ≤ 0.010**
Effectiveness	0.290***	4079.725	0.000	***** p ≤ 0.001**

Table 7: Hypothesis Results

Hyp.	Content	Results
H_{1a}	Organisational support is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.	(i) and (iii) not supported **(ii) weakly supported**
H_{1b}	Organisational support is positively related to effectiveness.	**weakly supported**
H_{2a}	Group size is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.	**(i, ii) strongly supported** **(iii) supported**
H_{2b}	Group size is positively related to effectiveness.	**weakly supported**
H_{3a}	Shared experience is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.	**(i) supported** **(iii) strongly supported**
H_{3b}	Shared experience is positively related to effectiveness.	**strongly supported**
H_{4a}	Group heterogeneity is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.	**(i) strongly supported** (ii) and (iii) not supported
H_{4b}	Group heterogeneity is positively related to effectiveness.	not supported
H_{5a}	Member competency is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.	not supported
H_{5b}	Member competency is positively related to effectiveness.	not supported (inverse effect)
H_{6a}	Member activeness is positively related to the group process variables: (i) group production; (ii) group well-being; and (iii) member support.	**(ii) and (iii) weakly supported** (i) inverse effect
H_{6b}	Member activeness is positively related effectiveness.	**weakly supported**
H_{7}	Group production is positively related to effectiveness.	not supported
H_{8}	Group well-being is positively related to effectiveness.	not supported
H_{9}	Member support is positively related to effectiveness.	not supported

Moreover, the results confirmed that organisational support plays a role on open content group effectiveness. Thus, organisational support in the context of open content groups seems to be more about affecting quality rather than quantity of group tasks. Although somewhat counterintuitive, this seems to indicate that promoting certain tasks as high priority might not increase the amount of activity on them, but maybe this merely reflects the voluntary nature of most of this effort. However it might attain the desired result of increasing quality.

The strongest predictor of both group processes and effectiveness was shared experience. First, a high degree of shared experience stimulates open groups to produce more. However, shared experience was not related to group well-being. Since people with a high level of shared experience are used to working together, there is less need for interaction and synchronization: they already know one another, and what they have to do. The synergy among the group members helps them in focusing mainly on their production tasks without much interaction, but leaves space and time for friendly exchange.

In our study, group heterogeneity was not found to have any influence on the group well-being and member support functions. Thus, there may be less motivation for interaction. In addition, group heterogeneity was not directly related to effectiveness, possibly because the size of open content groups is much larger than regular work groups. Moreover, our findings were for heterogeneity in member activity, not in demographic characteristics.

Member competency was operationalized in terms of average member tenure and average

member status in the community (administrators or regular contributors). An administrator is a user who has been an active Wikipedia contributor for a while and is a known and trusted member of the community. He or she tends to be responsible for dealing with high-level managerial tasks such as discussing policies, solving conflicts, addressing suggestions or recommendations by other members of the community. Although Wikipedia administrative status personel have been shown to reflect a member's social capital in the community [27], member competency in our study was not related to any of the group process variables. We found a significant negative relationship between member competency and effectiveness.

GROUP FUNCTIONS IN OPEN CONTENT GROUPS

66% of the variation of group production was explained by the input variables. Group size was the most influential factor (path = 0.463) followed by group heterogeneity (0.316) and then shared experience (0.216). This indicated that open content group production was stimulated by larger groups, a high activity diversity of its members, and shared experience. Although experienced members might collaborate on the same articles, a community should explicitly encourage new members to work on tasks in which active members are present.

About 35% of the variation of group well-being was explained. The most influential factors were group size, member activeness, and organisational support. Group well-being was not influenced by shared experience, group heterogeneity, or member competency.

38% of the variation of the member support function was explained by the proposed input factors. The most influential were: shared experience, group size, and member activeness. Member support was not related to organisational support, group heterogeneity, or member competency. This is in direct contrast to the factors that improve group-wellbeing (other than group size), which are all directly task-related.

PREDICTING OPEN CONTENT GROUP EFFECTIVENESS

Open content group effectiveness was influenced by all of the three categories of group inputs: environmental, group, and individual. The support of the community is important in increasing the quality of open content projects as it stimulates group members to collaborate and interact more. However, no direct relation was found with any of the group processes, the effects of the input variables fully explained the variation in open content group effectiveness. However, a supplementary PLS analysis of the process variables as independent variables and group effectiveness as the dependent variable, revealed that around 25% of the variation of effectiveness was explained, the largest path being group production, followed by group well-being and member support. First, this confirms the basic belief that the main factor for producing quality open content group projects is through the group production function, which basically means doing the actual job. Second, this analysis fully justifies the explanatory and behavioural importance of the process variables even though it clearly shows that no extra variation of open content group effectiveness is explained by these process variables beyond the variation explained by the input variables.

CONCLUSION

We have empirically confirmed the importance of group size in providing effective open content group material. More important, new light has been shed on the role of shared experience. Member activeness was also found to be a good explanatory factor of open content group behaviour. Other measures of group performance could have been used in this research project. Even though effectiveness through article featured status was the most appropriate and accurate measure, efficiency measures may

also provide insightful and complementary results. For example, a suggested efficiency measure in the context of Wikipedia may be the amount of time before reaching featured status nomination. Overall, our research project attempted to provide general results about both group behaviour and outcomes of open content groups. The influence of member characteristics on group processes and effectiveness was confirmed, highlighting the influence of member activeness on group well-being, member support, and group effectiveness.

Our study has shed further light on how open content projects create quality products. A significant contribution has been brought to both MIS research and group research by providing group insights from social psychology in investigating the factors that lead to high quality information-based products. The advent of the Internet challenges the time and geographical constraints of group collaboration by enabling new practices that rely on novel streams of thoughts. Open content is a nascent phenomenon that has started delivering on some of its promises.

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