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# Power of the Few vs. Wisdom of the Crowd: Wikipedia and the Rise of the Bourgeoisie

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## ABSTRACT

Wikipedia has been a resounding success story as a collaborative system with a low cost of online participation. However, **it is an open question whether the success of Wikipedia results from a “wisdom of crowds” type of effect in which a large number of people each make a small number of edits, or whether it is driven by a core group of “elite” users who do the lion’s share of the work.** In this study we examined how the influence of “elite” vs. “common” users changed over time in Wikipedia. **The results suggest that although Wikipedia was driven by the influence of “elite” users early on, more recently there has been a dramatic shift in workload to the “common” user.** We also show the same shift in del.icio.us, a very different type of social collaborative knowledge system. We discuss how these results mirror the dynamics found in more traditional social collectives, and how they can influence the design of new collaborative knowledge systems.

## Author Keywords

Wikipedia, Wiki, collaboration, collaborative knowledge systems, social tagging, delicious.

## ACM Classification Keywords

H.5.3.n. [Information Interfaces]: Group and Organization Interfaces - Collaborative computing, Web-based interaction, Computer-supported cooperative work; H.3.5 [Information Storage and Retrieval]: Online Information Systems; K.4.3 [Computers and Society]: Organizational Impacts – Computer-supported collaborative work.

## INTRODUCTION

Wikipedia is an online collaborative encyclopedia whose most distinctive feature has been its low cost of participation -- users do not even have to register to contribute. This openness to new users has been cited as both a source of strength and weakness [6]. Despite or because of it, Wikipedia has grown exponentially in users

and information since 2002 [14] and has been highlighted as a success story of low-cost collaborative knowledge systems.

The distinctive openness of Wikipedia suggests that one of its key strengths lies in attracting contributions from new users who may make few edits. This suggests a kind of “wisdom of crowds” effect” [12] in which a large number of people making small contributions can create a quality product.

However, many prominent Wikipedians argue that a small number of prolific users, rather than a large crowd, are the driving force behind the success of Wikipedia. For example, Jimmy Wales, the founder of Wikipedia, argues that most of the work on Wikipedia is done by a small number of users, citing that as of December 2004, 2.5% of the registered users on the site made half of the edits [15].

In a Sept. 4, 2006 post to his blog[11], Aaron Schwartz published the results of his study of several articles on Wikipedia suggesting that measured by the change in content of each edit, less-active users of Wikipedia are actually creating much of the text in these articles. Schwartz’ blog entry was slashdotted, and only deepened the mystery on who really writes Wikipedia. Is it the work of a few elites or is it the wisdom of the crowd?

Who does the work in Wikipedia has important implications both for the allocation of resources within Wikipedia and for the design of novel collaborative knowledge systems. Jimmy Wales has been quoted as saying “I spend a lot of time listening to those four or five hundred” top users [11], suggesting that the development of tools and features within Wikipedia may be targeted for the user groups that are most influential. Similarly, when designing a collaborative knowledge system it is important to predict who will be using the system for what purposes, and to make design decisions and feature choices that support important users.

In this study we examine the distribution of work in Wikipedia over time to answer the question of who does the work in Wikipedia. We examine “elite” vs. “common” user contributions over time, with the elite defined either by status (administrators) or by participation level (high-edit

users). Two different metrics (number of edits and change in content) provide converging evidence on an answer. Finally, to see whether the results found on Wikipedia generalize, we examine del.icio.us, a very different type of collaborative knowledge system.

## RELATED WORK

A number of studies have quantified the growth of Wikipedia as a network or graph [1][2][19]. These studies suggest that the dynamics of Wikipedia are consistent with those typically found in complex networks. They also find many characteristics in common across Wikipedias in different languages [19], and with the structure of the World Wide Web [1][2][19].

Voss showed that the content on Wikipedia has been growing exponentially since 2002 [14], whether measured by articles, words, links, or bytes, or users (though he only examined two classes of users: those making more than 5 edits in a month or more than 100 edits in a month). He also showed that the number of unique authors per articles follows a power law, as does the number of articles per author. Interestingly, these measures also appear consistent across Wikipedias of different languages (though with slightly different parameters), suggesting similar underlying generation processes.

Buriol et al. [1] found article and user growth consistent with Voss' findings. They additionally characterized user edits over time, showing that the average number of edits peaked in January 2003, and has been steadily declining since then. However, this analysis was aggregated across all users, precluding a more detailed breakdown.

Viegas et al. studied the edit patterns of articles through "history flow visualizations" [13]. In this technique they visualized how article edit histories changed, identifying sections of articles that changed or remained constant over time. They also examined the growth of 273 articles in Wikipedia, showing that only 21% of edits reduced the size of a page, with 6% reducing by more than 50 characters. However, their data was collected using the May 2003 Wikipedia; as we shall describe below, much has changed since then.

## METHODS

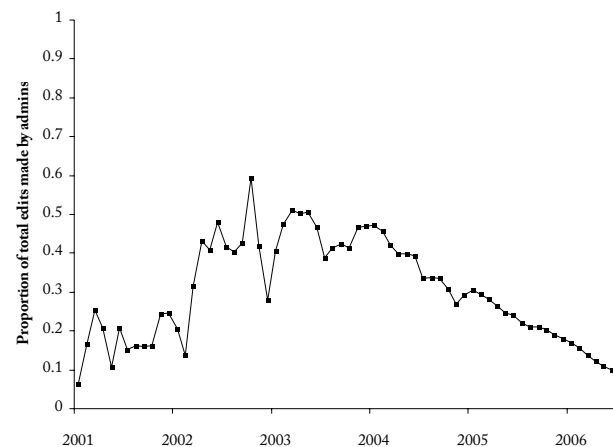
In the following analyses, we used a history dump of the English Wikipedia that was generated on 7/2/2006. The dump included over 58 million revisions, from more than 4.7 million wiki pages, of which 2.4 million are article-related entries in the encyclopedia. To process this data, we imported the raw text into the Hadoop [7] distributed computing environment running on a cluster of commodity machines, while importing the structure into a clone of the Wikipedia's own databases for direct analysis. The Hadoop infrastructure allowed us to quickly explore new content analysis techniques while minimizing code optimization time, while the database allowed us to inspect Wikipedia statistics in their native format.

To calculate the work done while editing an article, we calculated both the number of edits made and the change in content between edits. We model change as the number of words added and removed, as calculated by a traditional "diff" operation [9]. However, we used words as units instead of lines, allowing greater precision than previous studies (e.g., in [13], where the change of a comma would count an entire line as different). For both measures we aggregated edits over all 58+ million revisions, grouping by time and user participation level. User participation level was calculated based on the total number of edits made by a user.

## ANALYSIS

### Rise and Fall of Admins' Influence

We first examined the influence of Wikipedia administrators (admins). Admins consist of a small group of power users who have gone through a stringent peer selection process and can perform more types of actions than a regular user, such as temporarily blocking a page from being edited. Admins typically have an established track record of heavy editing and commitment to improving Wikipedia. In our Wikipedia data, there were 967 admins averaging 12,280 edits each. The admins represent an interesting "elite" group for these reasons: there are relatively few of them; they have a strong record of editing; and they have been peer-selected as belonging to a class trusted with more power than a normal user.



**Figure 1. Percentage of total edits made by admins.**

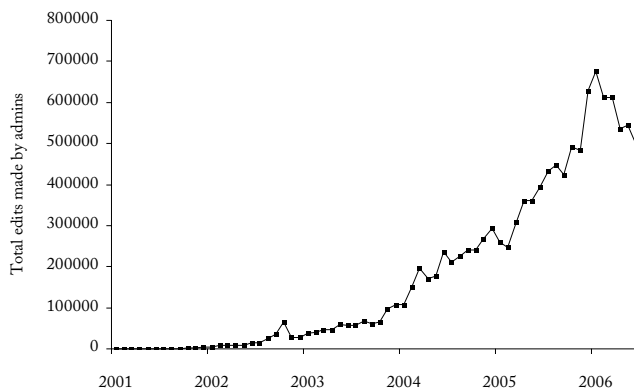
For each month in Wikipedia's history, we calculated admin influence as the number of edits made by admins divided by the total number of edits made in that month. Figure 1 shows the percentage of edits made by admins out of the total edits in Wikipedia. The figure shows a rise in the percentage of total edits made by admins to a peak of 59% of total edits in late 2002. This period of high influence lasted until 2004, at which time the data shows a decline in the percentage of edits made by admins that continues through the latest 2006 data, to a low of 10% of total edits.

Why is there such a dramatic decline in the proportion of edits made by administrators?

### Some Hypotheses for the Phenomenon

#### *Decrease in number of admins' edits*

One possibility is that this decline in admins' influence is driven by a decrease in the absolute number of edits made by admins. For example, admins may have a limited lifespan on Wikipedia and the decline could be a result of fewer admins making edits, or the same number of admins making fewer edits. To answer this question we calculated the number of edits made per month by admins. Figure 2 shows that the number of edits made by admins per month has been steadily rising. Although there is a dropoff in the graph toward the end in 2006, this cannot account for the dramatic decline which began in 2004.

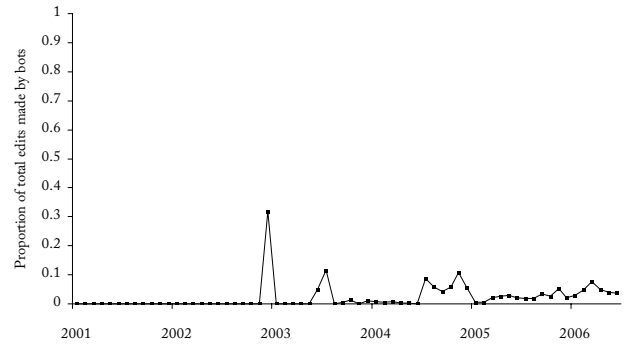


**Figure 2. Number of edits per month made by admins.**

This admin edit dropoff is an intriguing trend that merits further study. However, we believe that it may merely reflect the start-up time associated with becoming an admin. That is, some of the admins whose edits would contribute to that part of the curve will not attain admin status until sometime in the future, and so their edits are not yet counted in the graph. For example, a user joining in, say, February 2006, will not likely to have become an admin by July 2006, which is the latest data we have. We could not count this user's edits as admin edits, even though she might become an admin later.

#### *Bots made maintenance easier*

Another potential reason for the decline in admin edits is a reduction in the maintenance workload for administrators. There have been a number of automated bots created for use in Wikipedia which help with maintenance functions such as identifying and reverting vandalism and spam [18]. If these bots are taking over some of the workload that previously had to be done by admins, that might account for the decline in edit percentage seen in Figure 1. However, **Error! Reference source not found.** shows that this is not the case. The percentage of edits made by bots is fairly low and does not fit the declining admin pattern. Furthermore, the percentage of vandalism in Wikipedia does not appear to be decreasing [4].



**Figure 3. Percentage of total edits made by bots.**

### RISE OF THE CROWD

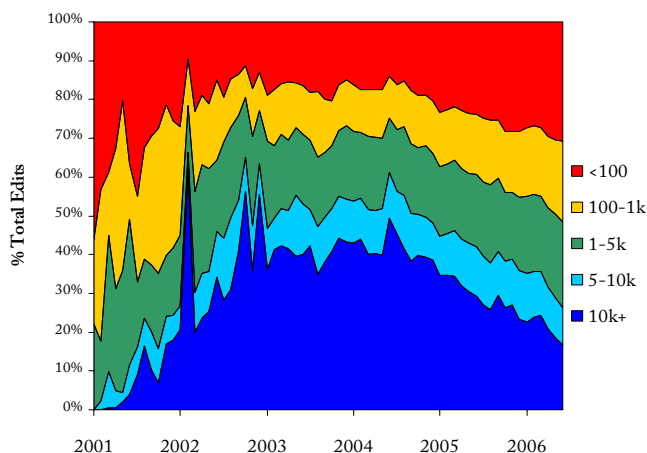
From the data above, the rise and decline of the percentage of edits made by admin users is a phenomenon that is not explained by a decrease in admin editing or workload.

Instead, it suggests the hypothesis that the decline could be due to a rise in the number of edits made by non-admins, which would support the idea of the growing influence of the masses. In the following, we use a different way of analyzing the distribution of work done in Wikipedia in order to test whether this is truly the case.

While the previous analyses dealt with the administrator user class, there are some advantages that can be gained by creating user classes by a different metric; specifically, the total number of edits made by a user. First, this allows us to verify that the rise and decline in influence found in the admin group applies to "elite" users and is not an artifact of being an admin. Second, this provides a data-driven metric which is not dependent on particularities of the admin selection process.

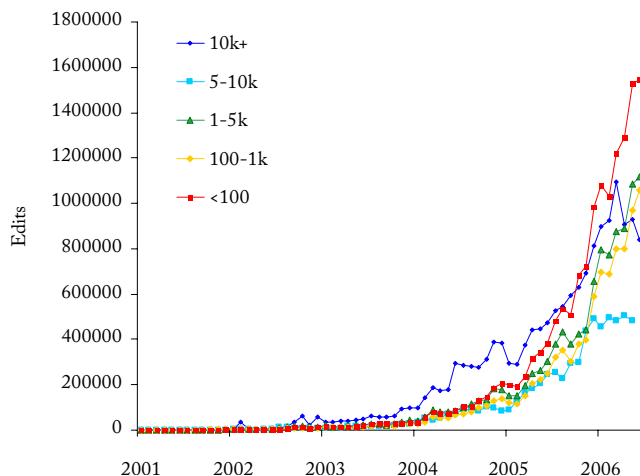
We classified users into one of five groups based on the total number of edits they made in Wikipedia: more than 10,000 edits (10k+); between 5,001 and 10,000 edits (5-10k); between 1,001 and 5,000 edits (1-5k); between 101 and 1000 edits (100-1k); and 100 or fewer edits (100-). We then calculated the percentage of total edits that each group made.

These percentages are shown in Figure 4. Importantly, the same pattern of rise, dominance, and decline as seen in the admins appears for the user class with the most edits (10k+) – the expert "elite". The decline of the "elite" users appears to be accompanied by an increase in the percentage of edits made by users with less than 100 edits – the novice "masses".



**Figure 4. Percentage of total edits made by users with differing editing levels.**

A different view of the interactions between groups can be seen in Figure 5, which shows the raw number of edits made by each user group per month. The number of edits made per month by each group increases over time to 2006. From this plot it is possible to see that the number of edits made by users with less than 100 edits has been growing much faster than the growth of the 10k+ group (or, indeed, any other group).



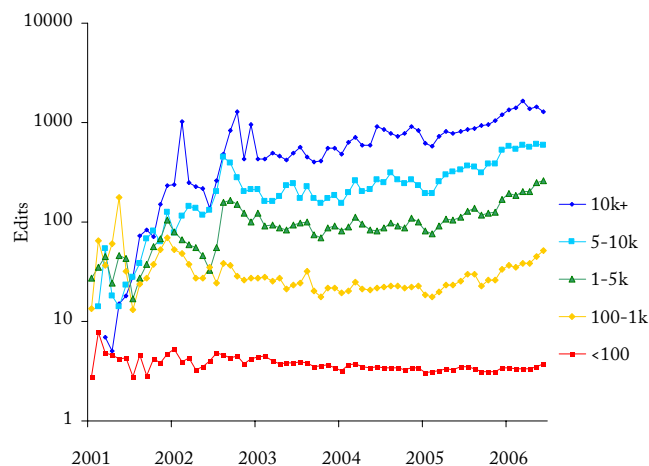
**Figure 5. Number of edits per month made by users with differing editing levels.**

Note that high-edit user influence is not accounted for by a decrease in their absolute activity since their edit rate increases from 2004 through 2006, while their proportion of edits is in decline. This is consistent with the admin data above.

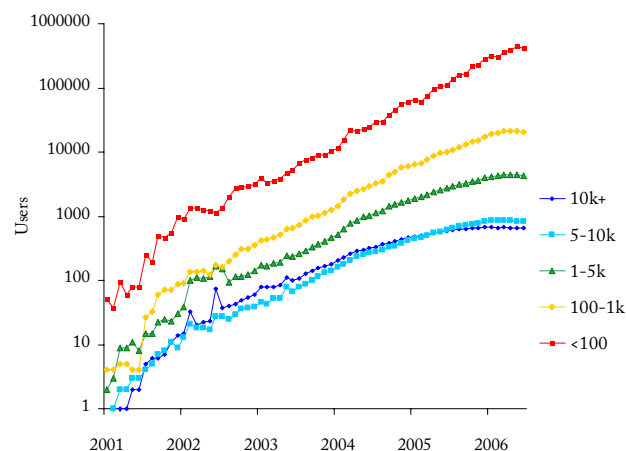
The above analyses demonstrate that the rise in edits by users with less than 100 edits is driving the declining proportion of high-edit user influence. However, what is accounting for the rise in edits by the low-edit group? Is this growth due to an increase in the population of low-edit users, or does it mark a shift in their editing pattern?

The editing rate for each user group is shown in Figure 6 (essentially, Figure 5 normalized by the number of users per group per month). The average number of edits per month for each user group appears to be relatively stable for much of the history of Wikipedia. While the low-edit group lines are bounded in their possible range (e.g., the group with less than 100 edits could not make an average of 100 or more edits per month), they are remarkably flat throughout. The 10k+ group also shows a non-decreasing pattern, providing further evidence that their decline in influence is not a result of a decline in absolute activity.

Figure 7 shows the raw population growth for each user group. All groups show exponential population growth, with a small leveling out of high-edit groups in 2006 that likely reflects the lag in a user being counted as part of that group.

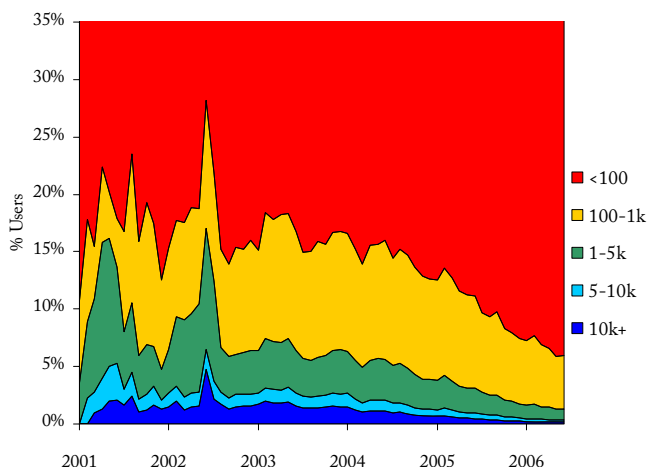


**Figure 6. Average number of edits per user per month.**



**Figure 7. Population growth for each user group.**

However, plotting the percentage of the total population made up by each user group shows that the low-edit group is increasing in size faster than the high-edit group (Figure 8). This is consistent with and accounts for the growth in total edits made by the low-edit group, and the proportional decline of edits made by the high-edit group.

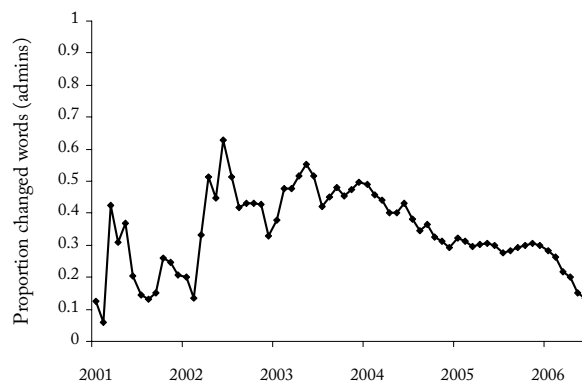


**Figure 8. Percentage of users in each user group over time.**

### CHANGE IN EDIT CONTENT

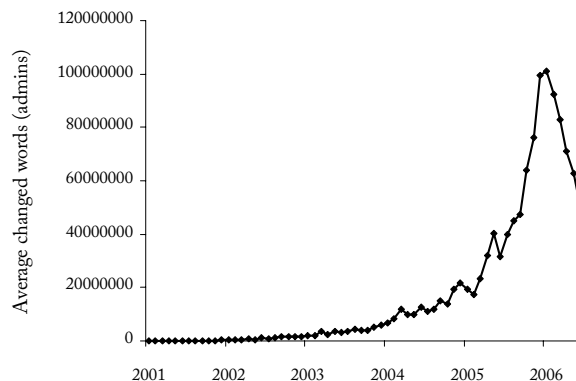
The previous analyses looked at the number of edits made by different types of users. However, an issue with these analyses is that edits themselves could differ greatly in the amount of changes to an article. By counting each edit instead of the length of each edit, we effectively treat, say, the deletion of a comma as equivalent to the addition of three paragraphs of text. Thus to characterize the amount and kinds of work done by different user types we need to analyze the change in content of each edit. Using distributed processing we were able to calculate the change in content for all 58+ million revisions on a word-by-word basis (see Methods for more details).

We first analyzed changes in content length made by admins. The percentage of words changed by admins out of the total changed words is shown in Figure 9. This shows that the number of words changed by admins peaked in mid-2002 at 63% of all changed words, but then declined to 13% in the current data. Thus it appears consistent with the data on raw edits shown in Figure 1. However, if we discount the 2006 data due to the lag effect described earlier, it looks like the percentage of words changed by admins during 2005 remained stable at approximately 30%. This is in marked contrast to the percentage of total edits made by admins, which declined steadily from about 30% to 10% during 2005 (see Figure 1).



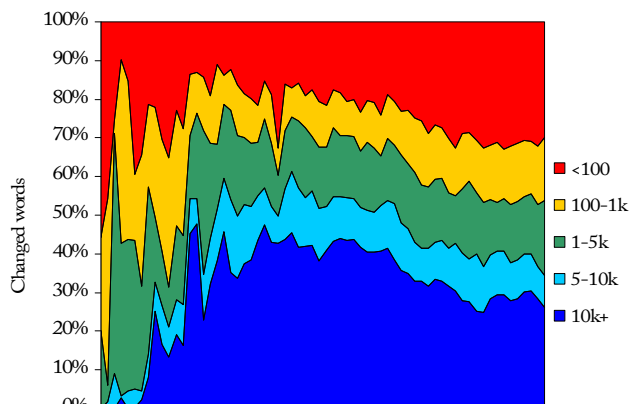
**Figure 9. Proportion of words changed by admins.**

Figure 10 shows the reason for this difference. Admins increased sharply in the number of words changed per month in the 2005-2006 period (again, the drop in 2006 is likely due to the lag effect). Thus, while the number of edits made by admins did not keep pace with the number made by other users, the average number of words changed per month made up for it, and resulted in what looks like a stable period.



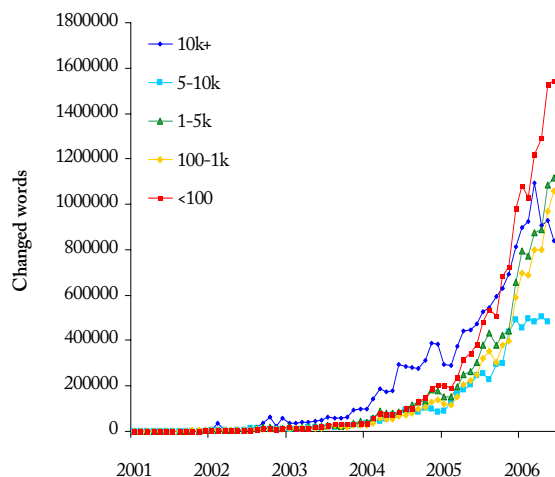
**Figure 10. Average words changed per month by admins.**

We also analyzed the data using the data-driven breakdown of users described earlier. Figure 11 shows the distribution of changed words over time as a function of user editing levels. The overall rise and decline of elite (10k+) user influence (from a peak of about 50% to the latest level of near 30%) is consistent with the trend found in Figure 4. However, like the analysis of the admins above, the percentage of work as measured by changed words remains higher than measured by total edits, remaining stable at about 30% during 2005.



**Figure 11. Percentage of changed words in edits made by users with differing editing levels.**

The average number of words changed per month is shown in Figure 12. Comparing this graph to Figure 5 shows that, remarkably, the number of words changed by elite users has kept up with changes made by novice users, even though the number of edits made by novice users has grown proportionately faster.



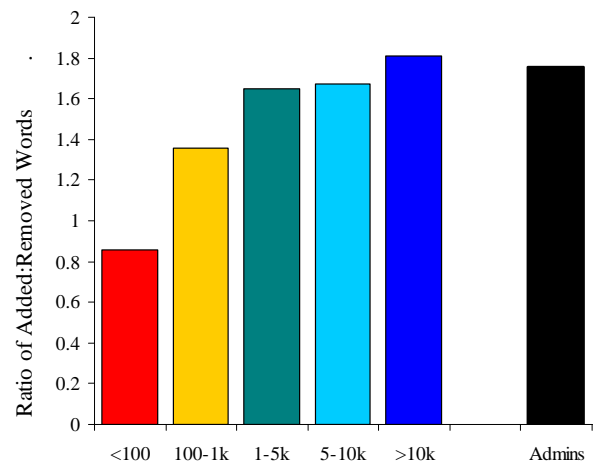
**Figure 12. Average words changed per month.**

The above data demonstrate that the rise and decline of the influence of elite users found above does not depend on the type of metric used (either percentage of edits or percentage of changed content). However, while the percentage of edits declined sharply in the 2005-2006 period, the percentage of changed content has remained remarkably stable. Thus though their influence may have waned in recent years, elite users appear to continue to contribute a sizeable portion of the work done in Wikipedia.

Furthermore, based on the above data, edits by elite users appear to be substantial in nature. That is, they appear to be doing more than just fixing spelling errors or reformatting citations. One possibility accounting for this is that they

simply revert more than other others, and while reverting only takes a few clicks, it can look like many words have changed. However, an analysis removing revert edits does not substantially change the findings.

Another question is how different user editing levels differ in the type of edits they make. Schwartz proposed that although elite users make many edits, novice users are the ones contributing most of the new content [11]. In contrast, Wales suggests that elite users drive content creation while contributions from novice users tend to be more of the spelling error fixing variety [11]. We examined this issue by separately counting the total number of words added and deleted by different user types. The ratios of words added to words removed per revision are shown in Figure 13. As the user participation level increases, the ratio also rises, with novice (<100 edit) users adding .86 words for every word removed but elite and admins users having ratios much higher (1.81 and 1.76, respectively). These data suggest that the more experienced the user, the more content is contributed. Indeed, novice users appear to remove more content than they create. While this does not mean that their contributions are not valuable (removing unnecessary or low quality content can be an effective way of improving quality), it does suggest that experienced users tend to add more new content than novice users.



**Figure 13. Ratio of words added to words removed per revision for different user classes.**

### SHIFTS IN OTHER ONLINE SYSTEMS: DELICIOUS.US

Is the rise and decline of elite users specific to Wikipedia or is it a more general phenomenon found in growing collaborative knowledge systems? To address this question we examined the distribution of work over time in another social collaborative system: delicious.us.

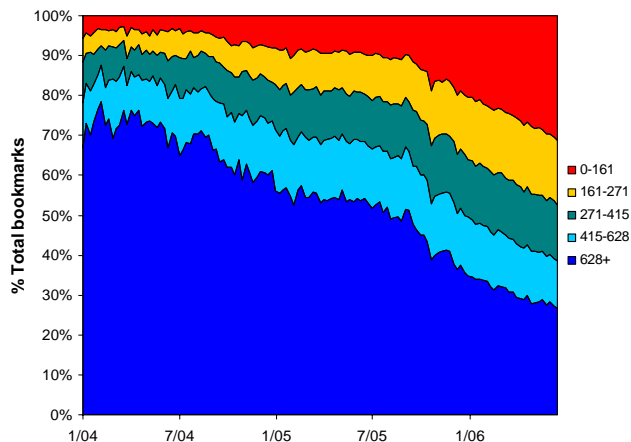
Delicious.us is a popular site on which users bookmark web pages using free-form tags rather than fixed categories. Web pages can exist with multiple tags, and tags can have multiple associated web pages, unlike a traditional



classification organization. The social nature of del.icio.us arises from users' ability to see what others have tagged. They can also see the most popular pages overall or for specific tags, leading to an impromptu ranking system for highly tagged pages.

A key difference between del.icio.us and Wikipedia is that the former does not promote direct interaction between users; instead, its power derives from the aggregation of many users' individual data. As such it is an interesting contrast case to the high degree of interaction found in Wikipedia.

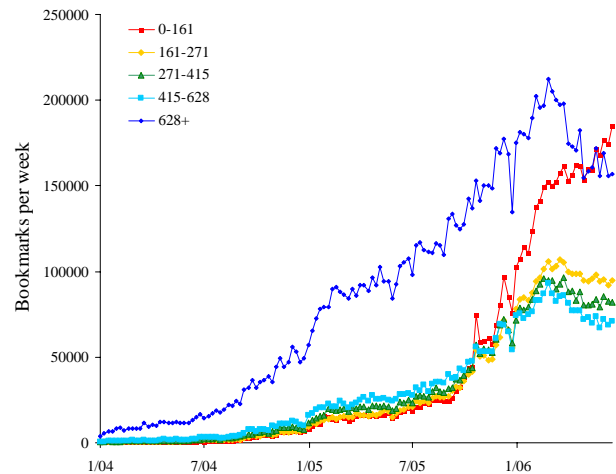
We examined the distribution of work over time in del.icio.us as measured by the number of bookmarks added per user. As in the earlier analysis, users were split into classes based on their total number of bookmarks added. Figure 14 shows the percentage of bookmarks made by different user classes. As in Wikipedia, we see a marked decline in the percentage of edits made by the highest-edit class from a high of 78% to a low of 27% in the latest data (June 2006). There is a corresponding rise in the lowest-edit class, from a low of 3% to the current high of 31%. Note that del.icio.us shows only a steady decline in the influence of elite users, with no initial rise as seen in Wikipedia. This is an intriguing difference that merits further study.



**Figure 14. Percentage of bookmarks made by different user classes in del.icio.us.**

Figure 15 shows the number of bookmarks per week for the different user classes. This figure is evidence that, like Wikipedia, the steady decline of elite user influence is not due to a decrease in their participation: the highest-bookmark users continue to increase in participation throughout the years. (The dip in 2006 is likely due to lag effects in amassing enough bookmarks to be considered part of the elite group, just as we saw in Wikipedia. It cannot account for the continued decline of elite influence since 2004.) Instead, the effect appears to be driven by the growth in low participation users. Thus although del.icio.us, like Wikipedia, continues to grow, there is a

dramatic shift in influence from the power of the few to the rise of the crowds.



**Figure 15. Number of bookmarks per week for different user classes.**

## DISCUSSION

Although the population and content of Wikipedia appear to be in continued exponential growth, a closer look revealed a major shift in the distribution of work in the system. We discovered an initial rise and subsequent decline in the influence of “elite” users. This result held true whether elite users were defined by peer-selected groups (administrators) or data-driven groups (high-edit users). We demonstrated that this decline was not due to a decrease in elite user activity or to shifts in user group editing patterns, but instead was driven by marked growth in the population of low-edit users – the rise of the bourgeoisie. These results were consistent whether the data were analyzed by edit count or by the actual change in content.

We also examined del.icio.us, a social collaborative bookmarking site which has also experienced tremendous growth. Again we discovered a shift in the distribution of work from the elite (high bookmark) to the novice (low bookmark) users. This raises the intriguing hypothesis that this change of influence over time may be a typical phenomenon of online collaborative knowledge systems and may occur despite what appears to be constant continued overall growth.

One way of viewing the shift in influence from elite users to novice users is as a process of technology adoption [10]. Elite users are the early adopters who select and refine the technology. They are followed by a majority of novice users who begin to be the primary users of the system.



However, collaborative products like Wikipedia are different from traditional technology products in that the product itself changes as a direct result of adoption. That is, the end user who begins participating in Wikipedia immediately has an effect on it. In this sense collaborative products resemble dynamic social systems more than fixed products, as they are in a state of constant change based on the prevailing opinions of the population.

For such systems to spread, early participants must generate sufficient utility in the system for the larger masses to find value in low cost participation. Like the first pioneers or the founders of a startup company, the elite few who drove the early growth of Wikipedia generated enough utility for it to take off as a more commons-oriented production model; without them, it is unlikely that Wikipedia would have succeeded. Just as the first pioneers built infrastructure which diminished future migration costs, the early elite users of Wikipedia built up enough content, procedures, and guidelines to make Wikipedia into a useful tool that promoted and rewarded participation by new users.

To carry the analogy further, as emerging social systems grow, the influence of the early founders begins to wane. The people who start a company are rarely the same as those who run it; the pioneers were dwarfed by the influx of settlers. Similarly, the influence of elite users whose contributions drove Wikipedia until recently has been shifting to the novice masses. With such population growth comes the need for structure, procedure, and hierarchies.

Already there is evidence of increasing structure and bureaucracy evolving to handle system growth. Until 2004, the arbiter of serious disputes and the only person with the ability to ban non-vandal users was Jimmy Wales [16]; since then an Arbitration committee has been established to do so, as well as a Mediation committee which focuses on helping users resolve their disputes before they reach the level of needing arbitration. Informal structures have also been evolved, such as the Mediation Cabal -- an unofficial group of normal users who try to help mediate disputes -- and the Association of Members' Advocates.

This view of Wikipedia as an emerging social system suggests that it may be entering a critical period. The recent massive influx of low-participation users has resulted in a large shift in the distribution of work done in the system. How Wikipedia reacts to this shift may be a major determinant of its future viability and continued growth.

#### *Future Directions and Application*

These findings suggest additional avenues for further research. First, do social stratifications (the hierarchical arrangement of social classes within a society) happen in other social collaborative systems? There are some anecdotal evidences that social stratification does happen in open-source development [1], multi-player online games [5], and bulletin board systems such as Slashdot [8].

Second, another research question is "what causes the social stratification in the Wikipedia society?" Do stratifications from other online communities result directly from an increase in participation by common classes of users? Interestingly, in sociology, social stratification is believed by proponents of structural-functional theory to be beneficial in stabilizing the existence of societies. Conflict theorists such as Max Weber believe stratification occurs due to status and power differentials [17]. Viewed from this perspective, the invention of the admins class in Wikipedia could have predicted the stratification of the Wiki-society. The clear subsequent shift in power among levels of stratification is an intriguing trend that merits study in other online social systems.

The results described here also have implications for the design of collaborative knowledge systems. One recommendation is that during the early phase of the system resources should initially be allocated towards building tools for power users and improving expert features, as this is the population driving early growth. However, as the population increases resources should be shifted towards improving ease of use and effectiveness for novice users, as well as developing structures and procedures that can support a large influx of users. It also suggests that designers should continue to reevaluate the user population in anticipation of the shifts seen here.

#### **CONCLUSION**

Wikipedia's growth as a reference tool and an online community has caught the attention of researchers worldwide. Little is currently known about the dynamics of its social structure. A current raging debate is "who writes Wikipedia?" Is it the work of a small group of elite users, or is it the input from the wisdom of a large crowd?

In this paper, we show that the story is more complex than explanations offered before. In the beginning, elite users contributed the majority of the work in Wikipedia. However, beginning in 2004 there was a dramatic shift in the distribution of work to the common users, with a corresponding decline in the influence of the elite. These results did not depend on whether work was measured by edits or by actual change in content, though the content analysis showed that elite users add more words per edit than novice users (who on average remove more words than they added). The decline of elite user influence was also shown to occur in del.icio.us, a social collaborative knowledge system with a very different participation structure from Wikipedia, suggesting that it may be a common phenomenon in the evolution of online collaborative knowledge systems. The data presented in this paper suggest that user dynamics in Wiki-society merit further study and provide insights into allocating resources when building online collaborative knowledge systems.

## ACKNOWLEDGMENTS

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