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Performance implications of stage-wise lead user participation in software development problem solving

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ABSTRACT

The problem-solving view of new product development sees the innovation process as a series of problem-solving loops broken down into three stages: problem detection, analysis and removal. We link this framework with lead user-driven innovation regarding software and show that effort by lead users (LUs) in each stage of the innovation problem solving process is, in varying degrees, associated with the source code's quality, the productivity of the development process and the software's popularity. We also test whether front loading the problem solving process is associated with development performance and we find that front loading is associated with increased code quality but decreased development productivity. Empirical tests are carried out with data from open source software projects. Findings potentially impact the design and management of online communities to help product development.

1. Introduction

Despite the obvious economic importance of software projects, a great number of new software development projects cannot be considered successful, with end products plagued by quality issues, not to mention projects that are routinely late or extremely over budget. While estimates of failure rates range between 15% and 70% [36,84] depending on the kind of software project and how success is measured, it is generally accepted that the economic and social consequences of unsuccessful software development projects warrant continued attention from practitioners and academia [44].

Various development management methodologies have been advanced to alleviate new software development problems, for instance agile or lean development, with varying rates of success [25]. A relatively recent trend in innovation can, however, complement most project management techniques: the concept of user aided innovation.

User-aided innovation – the development of new products with active help from users – was placed in the research agenda by Von Hippel [94], followed up by a relatively recent stream of studies [39,50,61,97]. These works particularly highlight users who experience product related needs well ahead of the mainstream consumer and stand to benefit significantly from product modifications, so much that they often carry those modifications out themselves. These users are called "lead users" (LUs) [94].

LU involvement in product development has been documented in areas as diverse as industrial equipment and extreme sports gear [77]. The software industry can be considered a pioneer in exploiting this resource. For instance, long ago before the concept of the LU was coined, it became standard practice in the software industry to get select user feedback by limitedly releasing "beta" versions. Software manufacturers, especially in the gaming industry, routinely facilitate tools that enable advanced users to produce modifications or "mods", some of which are eventually incorporated into the official version of a product [75]. Early studies on LU innovation were carried out looking at industrial control systems [92], and open source software has been repeatedly cited as a prototypical case of LU involvement [10,43,99]. Some proprietary software companies have experimented with the concept of LU involvement to aid their product development processes, like Microsoft did with its Most Valuable Professionals (MVP) program [70] or Dell with its Idea Storm community [24].

Through online communities, software LUs can provide ideas for features [99] or inform developers of defects in a product and discuss alternative strategies to solve these problems, even suggesting specific solutions. It is interesting to note that LU involvement in software development is related mainly to defect reporting, analysis and repair [18,31,56]. These activities closely match the three main stages in the innovation problem solving process: problem detection, analysis and removal [47,49].

User-aided innovation's advantages and problems have mostly been studied in company-led settings [33,45,63]. However, alongside potential benefits, involving LUs in the software development process through online LU communities poses several particular challenges. First, participation in online user communities is mostly voluntary, and motivating LUs to participate in the development process is a prime concern [7]. Second, user-aided problem solving activities can

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occur simultaneously; i.e. more than a single defect can be worked on by LUs at any given time, and LUs usually prioritize their work according to their own desires and abilities rather than by a formal development blueprint or management dictated priorities, requiring some degree of coordination. Furthermore, LUs can choose to participate in any one or more of the stages of the problem solving process with different intensities and timings.

Project managers may need to spend substantial resources in order to coordinate and incorporate user input from the open source community [20]; contributions need to be screened for their value, feasibility and appropriateness to the project's technical and commercial objectives, and while part of this assessment can also be done with the LUs' help, the management team eventually decides whether to consider a detected defect, accept the proposed avenue to arrive at a solution or accept a specific solution proposal. Given that resources are limited, a reasonable research question of practical importance is: *What are the performance implications of encouraging LUs to work on problem detection, analysis or removal?* The innovation literature consistently refers to problem solving with regard to the development of a new product as a one-step action, but informed by the problem solving literature we can separately test problem detection, analysis and removal to observe a more nuanced picture.

Furthermore, managing LU contributions in the different stages of problem solving entails varying kinds of resources use as well as benefits, suggesting the potential existence of tradeoffs among the different dimensions of innovation success such as development productivity, code quality or development timeliness. For instance, while it is plausible to suggest that if the community has more LUs detecting defects we may eventually arrive at better code quality, the processing of LUs' input can hinder the development team's productivity. Another research question is: *Are there any performance tradeoffs involved in different LU participation intensities along the stages of the problem solving process?* Since innovation success is multidimensional, empirically testing several kinds of outcomes produces a more complete understanding of problem solving vs. innovation performance.

Also, timing in problem solving is important: Thomke and Fujimoto [90] looked at a few projects in the automobile industry and observed improvements in some product development performance metrics when they attempted to front load their product development process; i.e. favored early (rather than late) identification and solution of problems. Their study relied on handpicked projects and anecdotal evidence, in an environment devoid of LU participation. To date, empirical studies based on large samples and hard metrics about of the potential benefits of front loading in the context of LU participation are lacking. We attempt to fill such gap with this study. Our third research question is: *Is development performance associated with the relative promptness of LU participation in problem solving?*

Answering these questions is useful to design online communities and allocate resources to encourage or discourage user participation in the different stages of problem solving. For instance, a manager may wish to only get user feedback about defects but not engage LUs in problem resolution, while another may want to post in-house detected bugs for analysis by volunteers, depending on costs and desired outcomes.

This study draws from the problem solving and LU innovation literature to devise hypotheses that are tested using ordinary least squares models built from data extracted from software development projects. After this Introduction, Section 2 of the paper includes a review of the literature, leading to the hypotheses to be empirically tested. Section 3 explains the research setting, while analytical methods are developed in Section 4. Section 5 presents the results of the analyses, while Section 6 offers a discussion of the findings and Section 7 reviews the limitations of this study and its implications for future research.

2. Literature Review and Hypotheses

Users have been purposely and routinely involved at the market research stage of new product development in order to identify their needs, and help design or refine product offerings. For example, the use of focus groups is a widely known such practice [85]. Lately, the involvement of users has shifted to a more active role.

We know that innovations frequently originate from users' initiatives [27]. More recently, [93,94] it has been observed that a subgroup of users not only generates ideas for improvements to existing products but also they carry out modifications themselves, to address specific needs. These special users have been dubbed lead users or “LUs”. Two independent dimensions [33] are related to LUs: they 1) experience product-related needs well ahead of the mainstream consumers and 2) stand to significantly benefit from product modifications.

One stream of research focused on characteristics of LUs. They seem to have, compared to mainstream users, a longer use experience [78]. Many times, dissatisfaction with the current product features seems to trigger product modifications, and LUs possess some particular personality traits such as heightened locus of control and increased innovativeness [79]. LUs also display more willingness to collaborate, better product related functional knowledge and a high level of strategic alignment with a brand's identity [63,76]. They also tend to be opinion leaders rather than opinion seekers [77].

Another area of research looks at the consequences of LU innovation. LUs are sought not only because of the economic value of their suggestions, but because their needs predate those of the general market and solutions to problems they point out often can be transferred into other components of the development portfolio [94]. Innovations spawned by LUs are more likely to be breakthrough innovations and to produce relatively higher profit margins [26,59]. Products based on LU-generated ideas are more likely to become commercially attractive [92], and they are more original, but less feasible [55].

Though the performance of products under the LU innovation paradigm has been extensively researched, the performance of LU-driven development processes has received relatively little attention [32]. Previous studies suggested that LU involvement in idea generation could impact productivity or quality [92,94], but little empirical support is available, which this study intends to alleviate.

LUs can offer their contributions at the sponsoring firm's premises, as it is done by 3 M [60], but the Internet has given birth to firms' use of online product user communities to generate LU ecosystems. In these virtual spaces, by means of e-mail list servers, Internet relay chat rooms and bulletin boards, LUs can get in contact with each other and with personnel from the sponsoring firm. Product performance is discussed, defects reported, and modifications and solutions suggested to known problems. The relative lower cost of accessing LUs by this means vis-à-vis by face to face interaction allows online communities to be larger, remain active for longer proportions of the product development life cycle, and establish relatively stable memberships, which tends to be effective at preserving organizational learning [51].

Whether company sponsored or not, online product user communities exist for a wide range of products, from sporting equipment to music instruments to software [1,45]. In the software area, giants of proprietary hardware and software such as Dell [24] and Microsoft [70] invested substantive resources to tap into communities of LUs.

Outside of the proprietary software realm, open source software (OSS) projects have been repeatedly considered in studies about LU innovation [32,57,96]. OSS is software developed under licensing terms that make publicly available the complete source code of the product and allow the redistribution of modified versions. A prototype of the program is posted in a publicly viewable electronic repository and afterwards LUs contribute their work voluntarily, at varying skill levels, making intensive use of electronically mediated communication. OSS development is highly flexible and allows for the quick rearrangement of labor to adjust to changing priorities. The involvement of LUs in OSS development has been well documented and is considered key to its thriving [81,95].

The work carried out by LUs can be inscribed into the problem solving view of new product development [21,30]. This paradigm considers