An Approach to Investigating Proactive Knowledge Retention in OSS Communities

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Abstract. Open Source Software (OSS) is the manifestation of software developed and released under an "open source" license, meaning that under certain conditions; it is openly available for use, inspection, modification, and for redistribution free of cost, or with cost based on the license agreement. The transient nature of the OSS work force results in turnover induced knowledge loss in OSS projects. In this work, we examine the research methodology, which will contribute to the formation of proactive knowledge retention practices in OSS projects to transform contributor's use of knowledge and engagement in knowledge relevant activities including knowledge sharing and knowledge transfer.

Keywords: Open Source Software, Knowledge Loss, Proactive Knowledge Retention, Mixed Methods Research.

1 Introduction

Contributors in Open Source Software (OSS) projects interact on technology-mediated channels to acquire and to share knowledge such as mailing lists, forums, and Internet Relay Chat (IRC). The contributors who are skilled and experienced in a specific module of the project and may not explicitly share their acquired knowledge on their leaving, and therefore the project suffers from a knowledge gap. In contrast to contributors in OSS projects, employees in traditional software development organisation may be under contractual obligation to notify their employer before leaving the organisation and to fulfil a notice period during which knowledge transfer concerns can be addressed. The workforce in OSS projects is of a transient nature due to inevitable high turnover fate [1, 2] and further, departing contributors may not provide notice and in an instant, may no longer be available for the purpose of formal knowledge transfer activities.

OSS projects have a hierarchical onion-like structure (see Figure 1), consisting of core, co-developer, active users, and passive users [3-5]. The knowledge distribution among contributors in OSS projects is not uniform and absence of a contributor who is the original owner of the files or system in the project to perform maintenance tasks results in risking files to abandonment [6]. A small subset of contributors, typically 20%, called core members, make major code contributions of about 80% in OSS projects [3]. These 80% of the contributors, who make knowledge contributions in the form

of the code, can be considered the most knowledgeable ones on the project. As depicted in Fig. 1 of the onion model, knowledge distribution in OSS projects is non-uniform with a higher concentration of code contributors in the centre of the onion than in the outer layers. The focus of this research is on the uniform distribution of knowledge among contributors, by the introduction of continuous knowledge transfer techniques and practices, which we refer to as a proactive knowledge retention strategy for OSS projects. This paper presents the research methodology to investigate the knowledge loss problem in OSS projects articulated in [7]. The research methodology discusses the overall research approach to be employed to devise a proactive knowledge retention strategy in OSS projects.

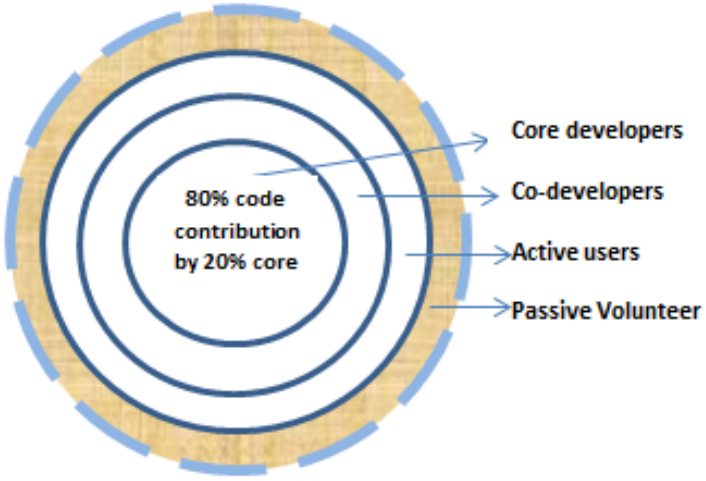

Fig. 1. Onion model representing contributors in OSS projects users [3-5]

2 Background

"Knowledge is information combined with experience, context, interpretation and reflection" [8]. In OSS projects knowledge generation is continuous through the process of knowledge creation and sharing and is cyclic in nature. There are two kinds of knowledge generated, namely tacit and explicit, where tacit knowledge being that has not been made explicit, that may for example be in the mind of one or more individuals but not documented [9]. Both tacit and explicit knowledge are inevitably created as software is produced, and the advent of agile software development [10] has placed an emphasis on reducing explicit documented knowledge. The impact of this development suggests a heightened demand to address tacit knowledge retention in software development projects. The knowledge loss due to the loss of experience and expertise on the project impacts productivity and additional time is required to learn the workings of the project when original contributors are no longer accessible [11]. The central hypothesis of this work states that*: The knowledge loss in OSS projects due to contributor turnover can be reduced by introducing proactive knowledge retention practices in OSS*

projects that can transform contributor's use of knowledge and engagement in knowledge relevant activities including knowledge sharing and knowledge transfer.

In OSS projects inevitable turnover due to the transient nature of contributors [2] and absence of contractual bindings for notification before contributors leave, make it difficult to enable any reactive knowledge transfer activity. Therefore, the reactive approach of knowledge retention that may be practised in a traditional software organisation may prove entirely ineffective for OSS projects. The central hypothesis stresses the need for proactive knowledge retention practices in OSS projects arising from the difference of organisational and governance structure between OSS and traditional software organisations. The central hypothesis leads to the first research question:

RQ1. What practices can enable effective proactive knowledge retention strategy in OSS projects?

OSS projects are dynamic, dispersed, with transient contributors concurrently performing tasks in different roles, and collaborating through technologically mediated channels. The challenge is to formulate the strategy for proactive knowledge retention, which can resonate with the idiosyncratic nature of OSS projects without causing an overhead to the productivity of the project and contributors. The OSS communities focus on self-direction and favour intrinsic value system and therefore imposing a strategy that calls for contributors to limit their freedom will lower their enthusiasm of doing well for the society. The next step after identification of retention practices requires their incorporation with the OSS projects work settings, which leads to the second research question:

RQ2. How to incorporate proactive knowledge retention strategy with established work practices in OSS projects?

3 Research Philosophy

Worldviews provide a general philosophical direction to research with common elements having different stances [12]. Philosophical worldviews shape the approach taken for research by influencing research designs and research methods [13]. Worldviews differ in: ontology which is the nature of reality; epistemology which refers to how we gain knowledge about what we know; axiology which explains role of values in research; methodology determines the process of research; and rhetoric is the language of research [14].

Three Worldviews

The three worldviews reflected as different philosophical concerns in research are positivism (also called post positivism), interpretivism, and pragmatism. Underlying philosophical concerns further determine the selection of the research method to conduct any research.

Positivism. The positivists advocate in the quantification of their learning through numbers and the use of statistical equations to predict human behaviour [15]. A positivist believes that social life is pretty stable and constant [16]. In such an approach, if the

learning of a concept is not possible through quantifiable methods it is generally ignored. The positivists extract simple relationships from a complex real world in numbers without considering the context [16]. Positivists stress deterministic philosophy, reductionism, observation and measurement, and theory verification [13]. In deterministic philosophy, causes determine the effects or outcomes. Reductionism is about reducing ideas into small discrete tests consisting of variables based on hypothesis and research questions. Knowledge development by positivist is through observing and measuring objective reality in numbers, and by verification of laws and theories that govern the world.

Interpretivism. Interpretivist focuses more on human thoughts and actions in social and organisational contexts [17]. Interpretivists (also called constructivists) believe in understanding the context and meaning by taking into account the real setting of the world in which they live and work. Interpretivist led research tends to develop subjective, varied, and multiple meanings about an object enabling them to unfold complex views [13]. The views on the situation being studied are collected from as many participants as possible [13]. For example, in open-ended questioning, a researcher carefully listens to the views of participants and shapes his or her interpretation from cultural and historical experiences [13]. Research led by an interpretivist generates or inductively develops a theory or pattern from the interpretation[13].

Pragmatism. advocates an alternative world view to positivism and interpretivism and primarily focuses on the problem to be researched and the consequences of the research [12]. Pragmatism offers a middle position or mixed methods research movement with a practical and outcome-oriented method of inquiry based on action and leads by enabling researchers to have better answers to their research questions [18]. Furthermore, pragmatism takes a value-oriented approach to research and reach an agreement about importance of culturally derived values and desired conclusion [18]. Pragmatism as a philosophical underpinning for mixed methods studies, focuses on the research problem [19]. Pragmatism uses pluralistic approaches to derive knowledge about the problem [19] and is concerned with real-world practice.

[redacted]Research Philosophy Adopted for the Current Study

The philosophical position adopted in this research is that of pragmatism, with a focus on the research problem and enabling empirical research to find answers to the research questions. The pragmatist worldview reflects the direct action oriented approach of a researcher towards the investigation of the research problem at hand. We sugest that this research would benefit by adopting pragmatism and approaching the problem by understanding it in a practical manner and by using multiple methods in research. The goal of this research is to devise a systematic strategy on the use of proactive knowledge retention practices in OSS projects. The development of an overarching proactive knowledge retention strategy requires understanding of the phenomenon and exploration in real life with multiple contexts and with the ability to quantify the concepts.

The view taken in this research is that of taking a middle position between two extremities of being a positivist or an interpretivist. Solely being an interpretivist or positivist is inadequate in terms of addressing the objective of this research. The insights provided by the use of qualitative and quantitative research in a mix method can be integrated into a workable solution under pragmatism [18]. The goal of mixed methods research is not to replace either qualitative or quantitative approach but to use their strengths and minimize the weaknesses of both in single research studies and across studies [18].

4 Eliciting Empirical Research Methodology

Empirical studies are emphasised to provide a scientific basis for software engineering [20] and to investigate the social and cognitive processes surrounding complex software systems [21]. Empirical methods allow for informed and well-grounded decisions and allow the investigation of a phenomenon by experimenting and experiencing it in the real world settings [20]. Methodology is defined as "the collection of methods or rules by which a particular piece of research is undertaken" and the "principles, theories and values that underpin a particular approach to research" [22]. Another definition states: "methodology is the overall approach to research linked to the paradigm or theoretical framework" [23]. In general, research methodology is a systematic approach to achieve particular goals of the research. The pragmatist worldview adopted in this research lays the foundation to the research methodology including the research design. Pragmatically inclined researchers focus more on the desired outcomes and solution to the problem. Mixed methods research applies pragmatist system of philosophy where "the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study" [18]. Research designs under each research approach provide specific directions and guidelines to conduct research [13]. The discussion on research design continues in section 4.1. The research method refers to "systematic modes, procedures or tools used for data collection and analysis." [23]. A method is mainly a set of principles through which empirical data is collected and analysed [24]. Research methods can be classified as qualitative, quantitative or both [20]. The details on research methods appear in section 4.2.

[redacted]Research Design

The research designs are the strategies of inquiry employed under a specific research approach. In this section, the research designs employed by three research approaches: qualitative, quantitative, and mixed methods are discussed.

Quantitative Approach. "The quantitative research mainly focus on deduction, confirmation, theory or hypothesis testing, explanation, prediction, standardized data collection, and statistical analysis." [18]. Quantitative research is based on the use of statistical methods and establishes relationships between variables [25] or quantifies a relationship by comparing two or more groups [13]. The aim is to identify a cause-effect

relationship. Quantification is the confirmation of a hypotheses rather than the formation of the hypothesis [26]. Quantitative research employs numbers to capture or describe some phenomenon but may be limited in the sense that it can overlook certain important information [15]. The strategies of inquiry employed in quantitative research are experimental designs such as true experiments and quasi-experiments, and non-experimental design such as surveys [13].

Experiments determine that if special treatment to a group can influence an outcome. Controlled experiments are quantitative in nature since they measure different variables and attain varying results. The variables are repetitively changed and measured again [20]. The variables to be measured in quantitative research are identified based on the theory [24]. In controlled experiments a cause and effect relationship is studied by manipulating independent variables and observing the effect on dependent variables [24]. Controlled experiments are sometimes referred to as research in small [27] and have a limited scope. The controlled experiments have a fixed design and the procedure to run an experiment is a formal one. In surveys, the primary means of gathering data are interviews or questionnaires which are sent to a large number of representing population [20]. When conducting a survey, a sample of a representative population is selected based on criteria and results may be generalised for the sample population. The survey has to be designed carefully ensuring that the questions are understandable by the participant and the data collected from the target population is valid and useful for the study.

Qualitative Approach. Qualitative research refers to the study of objects in their natural setting [20]. A qualitative researcher tries to understand the causes while interpreting a phenomenon by accepting that there are multiple interpretations of the explanations given to them by the subjects in the study [28]. The subject is the person who takes participates in the study to evaluate an object [20]. Qualitative research believes in a range of different ways of interpretation and understanding views of the subjects on the concerned problem at hand [20]. Case studies, ethnographies, post-mortem analysis, action research [21], phenomenology, grounded theory, and narrative [13] are primarily qualitative in nature.

A case study investigates a contemporary phenomenon in a real life context and the control is lower than with experiments. Case studies provides the richer and deeper description of the studied phenomenon [25]. A case study is an observational study on an ongoing project, while experiment is a controlled study [24]. It has been noted that case studies can combine data collection by using methods such as interviews, questionnaires, archives, and observations [29]. Similarly, a case study can also embed other research methods e.g. a survey may be conducted within a case study [25]. The use of mixed method approach explains that survey can be used within a case study [30]. Ethnography is another research method applied in a participant-observer manner [21]. The researcher participates with the team members to observe and understand the social interaction taking place in the community [24]. In action research, the researcher applies an iterative problem solving approach to a current situation to improve it [24]. The action research method requires an agreement from the problem owner(s) to collaborate and identify the problem..

Phenomenological research is a design originating from philosophy and psychology where the researcher describes the experiences of participants about a phenomenon as provide by participants [13]. The details provided on experiences of several participants about a phenomenon develops into a core description of a phenomenon under study [13]. Phenomenological design strongly underpins the philosophical attributes of a research topic and involves conducting interviews [31]. Grounded theory is another qualitative research design of inquiry from sociology, which facilitates the researcher in deriving a general, abstract theory about a process, action, or interaction grounded in the views of participants [13]. The data collection involves using multiple stages until a data saturation point is reached and no new information is found, the data refinement is through interrelationship of categories of information [32].

Mixed Methods Approach. "Mixed methods research is formally defined as the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study " [18]. Mixed methods involves combining qualitative and quantitative research by the collecting qualitative data, which is open-ended and without predetermined responses, and quantitative data, which is closed-ended in nature and the selection of responses is from predetermined list of answers [13]. The mixed methods are valued and thought to neutralize the weakness and bias that arises in research by the usage of just one method [13].

Research Design for the Current Study

In this work, mixed method research will be employed to investigate the research questions stated in section 2. The objective of this research is to identify a proactive knowledge retention strategy, which will elaborate a set of effective knowledge retention practices in OSS projects. Mixed method research emerges from pragmatism, a worldview that offers to combine the positivist view of quantifying the object of research and the interpretivist view of interpreting different meanings associated with it. Therefore, both research types, qualitative and quantitative, which merge in mixed method research design, will serve the purpose of understanding the phenomenon of knowledge retention in OSS projects and generalizing the results to a larger community of OSS projects. This research will adopt a mixed method approach with qualitative and quantitative data collection and an independent data analysis for each data type. The findings from analysis will be merged to understand and elaborate the phenomenon of proactive knowledge retention in OSS projects.

In this research, the rationale of using mixed method research is related to triangulation, complementarity, and expansion. Using qualitative and quantitative methods will facilitate a triangulation of results from different perspectives on the phenomenon of knowledge retention in OSS projects. Complementarity will further play an essential role to use one method to elaborate and clarify the results obtained from the other method i.e. complementing the results of quantitative methods with the help of the qualitative method. Using different methods for different inquiry components will also expand the breadth and range for descriptive research. At a practical level, mixed methods

has its strength, for utilising both qualitative and quantitative research to overcome the limitation of each approach; at a practical level the mixed method approach is complex and sophisticated; and at a procedural level, a mixed method approach provides offers the potential to establish a more rounded understanding of the problem [13].

Research Methods

This section elaborates the research methods employed for empirical data collection and the selection of research method considered suitable for this research.

- **Quantitative Method:** Focus on data collection that is largely of a numeric type and the required information is specified in advance and data is gathered using scaled instruments while interpretations are made on the basis of the statistical results [13]. The use of a questionnaire most likely includes a numerical rating scale for quantitative data collection [18]. In order to collect data, researchers can employ an instrument or test, which has a set of questions to evaluate the confidence towards an approach, or use checklist to identify and observe people involved in some task [13].
- **Qualitative Method:** Data collection involve observing the behaviour of individuals and conducting interviews with individuals where they can talk about a topic openly mostly without the use of specific questions. Researchers make interpretations from the themes or patterns that emerge from the data. Qualitative research theory may be applied after the data collection while following the process of coding (data analyses by labelling and categorising) [24].
- **Mixed Method Data Collection:** Here data collection comprises of both types of data quantitative and qualitative, to measure the concepts, parallel variables, or constructs, under study [13]. Both kinds of data is collected such as qualitative, which is open-ended and quantitative, which is closed-ended data to investigate research questions or hypotheses and the procedures for both qualitative and quantitative data analysis are detailed to perform analysis with adequate sampling, sources of information, data analysis steps.

Data Collection for Current Study. The data collection for the current study is by using mixed methods that involve both qualitative data and quantitative data. A survey instrument will be employed for qualitative and quantitative data collection. The purpose of the data collection using mixed methods will be to analyse and evaluate the proposed practices based on the feedback from the OSS community. Furthermore, the collected feedback from the OSS community will be utilised for improving the proposed practices for proactive knowledge retention in OSS projects. The questionnaire for survey interview will be prepared after examining the literature on practices and developing a set of proposed practices for proactive knowledge retention in OSS projects. Rather than using one type of data collection the combination of both quantitative data (close-ended questions with a larger sample) and qualitative data (open-ended questions with a smaller sample) overcomes the weakness arising from the use of only one data type. The analysis for each type of data collection will be performed separately and then results will be combined to understand the knowledge retention phenomenon in OSS projects.

Data Analysis

There are different possible ways in a mixed methods design, to converge or to merge the data from two different types of data collections. The two data collections are analysed separately and then results are explained. The two data collections can be merged by a side-by-side comparison, by transformation procedure and by table or graph [13]. In side-by-side comparison, the results from both types of data collection are reported separately and then findings are compared. In transformation procedure, the qualitative data is transformed to quantitative data by changing the qualitative themes into quantitative variables. The two types of data collection can also be merged in the form of tables and graph while display. In this research, the data analysis for quantitative and qualitative data will be performed independent of each other. The findings from both types of analysis will be combined to understand and elaborate the phenomenon. The results from the analysis of two data collections will be interpreted and produced in writing.

Validity Concerns

There are three key validity concerns while using the mixed method research. The first one is of unequal sample size when qualitative and quantitative data is collected [13]. Generally quantitative sample size is larger than qualitative sample size to perform statistical tests. The sample size for a qualitative data collection is small since the intension is to study the sample extensively and gain an in-depth perspective. The second concern is that it can be problematic to compare the findings from two data types with different variables and merge them will lead to incorrect strategy for inquiry [13]. In case of divergence, it can be difficult to explore the results any further. The third concern is to have the same participants in qualitative and quantitative data collection for a better comparison [13].

The qualitative and quantitative data collection will be conducted in such a way that both types of data are represented equally in the sample size of the survey questionnaire. The two types of data collection will be analysed separately by using side-by-side comparison. The results of both analyses will be merged and reported collectively. The design of the survey questionnaire will ensure that same concepts are measured in collection of both qualitative and quantitative data by removing any inconsistencies. The responses on qualitative and quantitative data will be collected simultaneously through survey questionnaire from each participant. The summary of the research methodology is illustrated in Figure 2, where rectangles represent survey design, data collection, or data analysis, while an oval represents merging the findings, interpreting, or incorporating them in OSS KR practices.

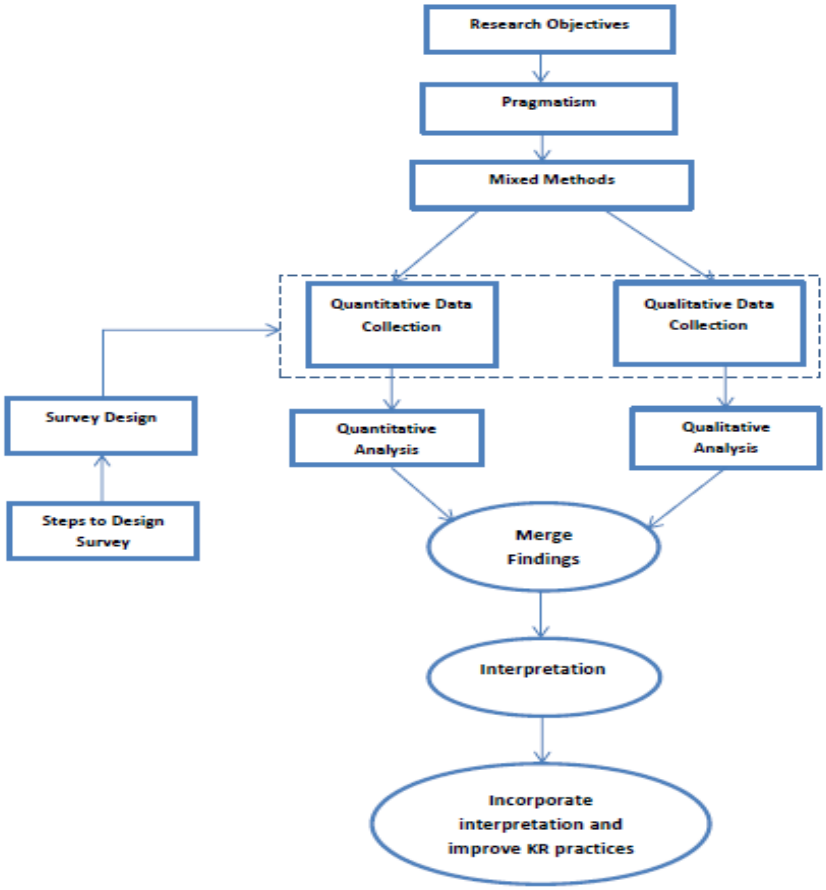

Fig. 2. The Research Methodology to investigate proactive knowledge retention in OSS projects

5 Future Work

The main goal of this research is to develop an overarching proactive knowledge retention strategy in OSS projects, something that we suggest is warranted based on a review of the literature and on the volatile nature of the OSS workforce. The mixed method research described in this paper establishes the baseline of the research methodology for the investigation of proactive knowledge retention in OSS projects. Moving onto the next phase to implement the research methodology, we will shift our focus to survey design. The research objectives will underpin the survey design and will align with the data collection in order to accomplish the research goals. In order to design the survey, selection of appropriate data components is required to develop a questionnaire and

gather valuable information from OSS communities. A streamlined process is required to identify the data components with a close examination of known and unknown information leading to the formation of an elaborative set of knowledge retention practices suitable for OSS projects. The analysis of the data collected through the anticipated surveys will facilitate in assessment, refinement and improvement of the knowledge retention practices in OSS projects based on the feedback from OSS community. The objective of this research is to improve proactive knowledge management as a counter-balance to the transient and sometimes uncommitted nature of OSS personnel. We suggest that the research methodology identified herein is appropriate to this research and that it will deliver tangible benefits for both contributors to OSS projects and consumers of OSS.

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