

## Who Will Remain? - An Evaluation of Actual Person-Job and Person-Team Fit to Predict Developer Retention in FLOSS Projects

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### Abstract

*Many businesses and private households rely on Free Libre Open Source Software (FLOSS). Due to a lack of sustained contributors, however, most FLOSS projects do not survive. The early identification of developers who are likely to remain is thus an eminent challenge for the management of FLOSS initiatives. Previous research has shown that individuals' subjective assessment is often inaccurate emphasizing the need to objectively evaluate retention behavior. Consistent with the concepts Person-Job (P-J) and Person-Team (P-T) fit from the traditional recruitment literature, we derive objective measures to predict developer retention in FLOSS projects. In an analysis of the contribution behavior of former Google Summer of Code (GSoC) students we reveal that the level of development experience and conversational knowledge is strongly associated with retention. Surprisingly, our analysis reveals that students with abilities that are underrepresented in the project and students with a higher academic education do not remain considerably longer.*

### 1. Introduction

Almost 70% of all webpages worldwide are served using Free Libre Open Source Software (FLOSS) [32] and 80% of European and North-American companies are relying on FLOSS applications every day [16]. However, a serious problem for FLOSS projects is the fluctuation among their contributors [21]. According to Robles et al., most developers' commitment is only temporary [37]. This has serious consequences for a FLOSS initiative. A lack of sustained contributors not only threatens the quality [47] and the release schedule [20] of a FLOSS project but also its entire existence [6]. Consequently, Hahn et al. consider a FLOSS project's ability to retain its developers most relevant for it to succeed [17]. Because the participation in FLOSS projects is generally open to everyone, project members have to select participants on whom they wish to spend their time and training efforts. The

prediction of newcomers' continued commitment is thereby a challenging task most team members are faced with. Crowston et al. show that FLOSS projects are quite similar to organizations in their efforts to identify and retain talent early on [7]. Previous research has already demonstrated that lessons from organizational staffing can and should be applied in FLOSS projects [5, 17]. However, concepts from professional recruitment have scarcely been used to assist developers' evaluation of newcomers so far.

This paper draws on concepts from organizational recruitment to suggest and validate an objective evaluation approach to assess the retention behavior of FLOSS developers. Therefore, Person-Job (P-J) and Person-Team (P-T) fit, two well established concepts from the recruitment literature, will be transferred to the FLOSS domain. P-J fit describes the suitability of an individual for a particular job [11] while P-T fit defines the relational compatibility between an individual and the existing team [50]. Prior research has revealed that both fit perspectives reliably indicate an individual's job satisfaction and performance [46, 50]. Because both satisfaction [22] and performance [35] have been found to also stimulate continued contributions in FLOSS projects and based on prior work [38] our research question is: Are P-J and P-T fit appropriate concepts to predict FLOSS developers' project retention?

Drawing upon organizational concepts, our research contributes to existing literature on FLOSS and on professional recruitment. First, our evaluation of P-J and P-T fit concepts will enrich existing research on the management perspective in FLOSS projects. In addition, our research has theoretical implications for organizational recruitment. Following Drucker's suggestion to regard knowledge workers as volunteers [10], our evaluation of recruiting concepts in a purely voluntarily driven context can also assist decisions on organizational staffing. Further, our research is relevant for FLOSS practice, as approximately 80% of FLOSS initiatives fail because of lacking sustained contributors [6]. Our work will help the management

of FLOSS initiatives to identify newcomers who are likely to remain so that it can actively support them in becoming long-term contributors. Further, novices' objective assessment enables team members to spend their time rather on new developers who are likely to stay than on newcomers with only a short-term interest in the project.

In order to suggest and evaluate an objective evaluation approach for developer retention in FLOSS projects, this paper is structured as follows: The next section will present our research background. A review of existing FLOSS research on developer retention is provided and the organizational constructs on which our research is based are detailed. Next, our research model is developed in section three and the corresponding research hypotheses are formulated. Section four describes our research methodology and the evaluation of our hypotheses based on the retention behavior of former Google Summer of Code (GSoc) students. In section five, the implications of our results are discussed. Finally, the limitations of our study are described.

## 2. Research Background

Following an overview of previous research on developer retention in FLOSS projects, in the second section, the two organizational constructs P-J and P-T fit on which our research is based are described.

### 2.1. FLOSS research

Despite its practical relevance, only little research has examined developer retention in FLOSS projects yet [13]. Studies approaching developer retention generally do so using the perspective of the individual developer. Thereby, intrinsic motivation, social ties with team members and project characteristics have been found most relevant for FLOSS developers to continue their commitment. In their motivation studies, Ke et al. and Shah show that intrinsic motives drive ongoing FLOSS participation [22, 42]. The researchers conclude that most developers continue contributing because it gives them a satisfying feeling. Subsequent research in this area by Fang et al. reveals that novices to FLOSS projects often arrive with an extrinsic, needs-driven, motivation [13]. Through social interactions with the project members [13] and successful contributions [35], the original motives, however, become intrinsic. Research by von Hippel et al. supports this finding and emphasizes the importance of communication via mailing lists for the development of social ties [19]. Using social resource theory Qureshi et al. demonstrate that newcomers stay active in a FLOSS project because they socialize with the

existing team [35]. Thereby, the ability to socialize depends largely on newcomers' existing relational behavior with the team. Other factors that have been shown to affect developer retention are project specific properties. Midha et al. show that the modularity and the complexity of a project's codebase have a significant influence on developers' continued commitment [30]. Moreover, previous research shows that the programming language, the employed technologies and the chosen licensing type have effects on novices' ongoing project participation [6].

Although prior research stresses the importance of newcomers' technical abilities and social interactions with the team members in order to continue their commitment, there is to our knowledge no conceptual approach to assess developers for these characteristics. In their early work, Pratyush et al. propose the notion of fit to explain turnover decisions in FLOSS projects [33]. Thereby, the researchers consider only the fit perceived by the newcomers themselves, making it unusable for their assessment from the project's perspective. With respect to organizational research which shows that an individual's subjective fit assessment is often inaccurate [3], the next section presents concepts from organizational recruiting that can be used to objectively evaluate newcomers' technical and relational fit with the project.

### 2.2 Theoretical concepts

The assessment of employees' retention behavior is a critical issue for organizations. In the organizational context, employees leaving their current employer cause not only direct costs but also significant indirect costs. While the monetary costs range between 90-200% of the annual salary [1] the dramatic consequences caused by knowledge losses, especially for software intensive companies, cannot even be estimated [8, 12]. It is therefore in an organization's vital interest to consider the future retention behavior of employees for their staff selection. Studies on recruiting practices show that interviewers' subjective judgment on applicants' future permanence is often inaccurate [3, 48]. Therefore, researchers recommend the use of objective fit measures to consider an applicants' suitability during the selection phase. As demonstrated in [28] the objective evaluation of applicants is especially important for jobs with high turnover rates. Two concepts which have been found valuable for the objective assessment of retention behavior are P-J and P-T fit. Both fit constructs belong to the overarching concept of Person-Environment (P-E) fit [40]. P-E fit originates from the interactionist theory of behavior. This theory is based on the assumption of Lewin that behavior is a function of the

person and the environment [26]. The match between the characteristics of the individual and the surrounding environment is thereby defined as P-E fit.

A recruiting concept that is traditionally used for the selection of employees is **P-J fit**. A common definition for P-J fit is provided by Edwards using a twofold description [11]. The first aspect Edwards considers is the congruence between an applicant's desires and the job supplies. The desire of an applicant is expressed by the goals [25], interests [4] and preferences which make the particular job attractive [34]. Correspondingly, the supplies of a job are defined by attributes such as pay [24] and participation in decision making [2]. The other aspect considered by Edwards for P-J fit is the match between the abilities of an individual and the demands of the job. The abilities of a person are operationalized by the experience [14] and the expertise he or she has already acquired [9]. Consistently, the demands of the job formulate the requisite skills and knowledge [15]. P-J fit has been repeatedly found to affect future job performance and satisfaction [22]. Being driven by these two factors Kristof-Brown et al. show that P-J fit is also a valuable indicator for retention behavior during the selection of employees [23].

Besides assessing the technical suitability, fit constructs have been found valuable to assist the evaluation of the relational compatibility between an individual and the surrounding environment [27]. A recruitment concept that is used to assess an applicant's level of interpersonal compatibility with the existing team is **P-T fit**. Researchers differentiate between supplementary and complementary fit to describe this construct [50]. Supplementary fit is high when a recruit has characteristics (e.g. attitudes or values) in common with existing team members [31]. Complementary fit, in contrast, requires that newcomers have distinctive characteristics that support or complement the characteristics of the existing team members [49]. The idea behind this form of fit is that deficiencies of single members are compensated by strengths of others [50]. Both complementary and supplementary fit have benefits and deficits when assessed singularly. A high level of supplementary fit tightens group cohesiveness and members' willingness to stay while possibly leading to uniform group thinking. Complementary fit, in contrast, improves the problem solving behavior of the team and, thus, its overall performance and creativity while disregarding interpersonal harmony. As a result, Kristof-Brown et al. conclude that both are relevant for assessing P-T fit of individuals [23].

### 3. Research Hypothesis

As in the case of organizations, the retention behavior of their contributors is a vital issue for FLOSS initiatives. In contrast to organizations, participation in FLOSS projects is generally open to everyone. In order to grow sustainably, FLOSS projects have to identify those contributors who will retain for longer so they can concentrate their training efforts on them. Despite the substantial differences between work in organizations and in FLOSS projects in terms of regulations and monetary rewards, the drivers for newcomers' sustained commitment are similar [22, 35]. Given this similarity, the generic applicability of P-J and P-T fit [27] and our previous research [38], both fit concepts serve next as methodological foundation for the early identification of long-term contributors.

With respect to the different characteristics between working relationships in organizations and FLOSS projects the definition of P-J fit has to be adjusted. In contrast to organizational contexts with their monetary rewards, FLOSS developers primarily feel attracted to projects because of surrounding characteristics. Therefore, the supplies of a FLOSS project are described by the working environment it provides for developers such as its codebase or the tools and documentation which make it easier for developers to contribute. Another supply of a FLOSS project is its reputation. Many developers are motivated to contribute by the wish to increase their standing in the community. To match this need, a FLOSS initiative needs an admired status in the corresponding developer community. Consistent with organizational literature, developers with a high fit between their needs and the project's supplies are supposed to be happier and more satisfied when contributing. As a result, FLOSS developers with a high needs-supply fit are assumed to remain longer than others in a FLOSS project.

Besides needs-supply match the definition of the demands-ability match has to be modified to be applicable in the FLOSS domain. In contrast to organizations, FLOSS projects have no job analysis from which they derive specific demands that can be used to assess a newcomer's aptitude. While prior experience with the project's codebase and existing development expertise have been found conducive for newcomers to successfully contribute [38], a FLOSS project's demands are generally much more focused towards newcomers' general contribution abilities than in the organizational context. Previous research has shown that through contributing successfully project novices continuously become intrinsically motivated which is in turn a key driver for their ongoing commitment to the project [22, 42]. As in the case of

organizations, newcomers with a high P-J fit are of special relevance for FLOSS projects. The match between individual needs and project supplies ensures that newcomers initially feel more satisfied when contributing to the project which increases their staying intention. The match between an individual's abilities and a project's demands also ensures that newcomers continue experiencing this higher level of satisfaction with their contributions and consequently continue their commitment. Therefore, it is assumed that:

**Hypothesis 1:** A FLOSS developer's assessed level of actual P-J fit is positively associated with his or her project retention.

In addition to the characteristics of the FLOSS project, previous research shows that novices' relational compatibility with the development team significantly influences their retention behavior. In line with traditional recruitment literature this interpersonal compatibility can be assessed using P-T fit. Following Werbel et al. both supplementary and complementary fit are assumed to affect newcomers' retention [50]. Scozzi et al. reveal that long-term contributors to FLOSS projects share mental models [41]. In his empirical study Solansky highlights the importance of a common mindset among project members for the individuals' identification with the team and so for their willingness to stay active in the project [43]. The researcher concludes that the degree to which team members share behavior and norms is most relevant for their continuance emphasizing the assessment of supplementary fit. The interactions between FLOSS developers are regarded as most relevant for their retention by von Hippel et al. [19]. Based on their research findings and existing literature in the organizational context, newcomers' supplementary fit influences their ongoing project participation.

Following organizational recruiting, newcomers' complementary fit is considered another important aspect for long-term commitment. According to Fang et al., developers' ongoing commitment is strongly affected by their recognition in the project's community [13]. Similarly, Roberts et al. show that developers with a status driven motivation are substantial for a FLOSS project [36]. Based on these findings, we expect that especially developers who possess abilities which have been underrepresented in the project before are recognized and valued by others and are consequently motivated to continue in the project. Therefore, newcomers assessed with a high supplementary and complementary fit are assumed to retain longer in the FLOSS project:

**Hypothesis 2:** A FLOSS developer's assessed level of actual P-T fit is positively associated with his or her project retention.

Studies on organizational recruitment practices show that interviewers' subjective assessment of P-J and P-T fit is commonly inaccurate and recommend the use of objective measures for the evaluation of newcomers. Cable et al. reveal that candidates' congruence with actual fit values has only a marginal effect on recruiters' fit perceptions [3]. Consequently, it is suggested to use objective measures to evaluate newcomers' fit. As in the case of organizations, FLOSS developers' subjective judgment of newcomers' fit characteristics is supposed to be less accurate for predicting retention behavior compared with objective measures [38]. Hence, it is assumed that:

**Hypothesis 3:** FLOSS developers' subjective assessment of newcomers' P-J and P-T fit is less accurate in predicting project retention than their objective evaluation.

#### 4. Research Methodology

The following study will test the three research hypotheses based on the retention behavior of former Google Summer of Code (GSoC) students to the KDE project. Every year Google supports GSoC students with a three month stipend for working at FLOSS projects during their summer break. In their application, students have to choose one of the participating FLOSS projects and detail what they would like to contribute to that project. Each FLOSS project then has to decide which applicants are accepted. One of the main projects to which students contribute during GSoC is KDE, the default desktop environment on many Linux distributions. As shown in Studer et al., developer retention is an important issue for KDE [45]. Hence, it is in the project's interest to select those students for GSoC who are likely to remain in the project. To do so, KDE relies for applicants' evaluation, on team members' subjective assessment. KDE's evaluation process of GSoC students is an adequate research evaluation for testing our hypothesis. It allows us to analyze in retrospect how students' actual P-J and P-T fit is associated with their retention behavior. Further, KDE's subjective evaluation practice of applicants allows us to compare the association between students' actual and perceptual fit assessment and their retention.

## 4.1 Measurement

The following assessment of students' **actual P-J** fit focuses on the match between their abilities and the project demands. Considering that students voluntarily select the FLOSS projects they would like to contribute to during GSoC and customize their proposals to their specific interests, needs-supply match is supposed to be high. Although the individual projects vary in topic and output, they all require that students apply their existing programming expertise and integrate their code into KDE's existing codebase. Consistent with organizational recruitment practices, students' relevant abilities for contributing to KDE are assessed by their academic education and their practical development experience. To assess students' academic education the year in which they started to study an IT-related course was considered. This information was extracted using students' online profile on LinkedIn, an international business related social-networking platform. Students not represented on this platform were surveyed by email about their educational background prior to GSoC. Besides their academic education, their development experience with any of KDE's more than 300 subprojects is considered. Relying on the same platform all of KDE's subprojects are generally written in C++ and use the same development toolchain. Every prior coding experience students have already acquired in any of KDE's subprojects is therefore considered to be relevant. To quantify students previous coding experience with KDE, all of their prior code contributions have been identified using the mailing list *kde.cvs.commit*. This mailing list aggregates every commit from all of KDE's subprojects. Indexing all posts of this mailing list, the online service markmail.org enabled us to reproduce all of a student's previous commits to KDE subprojects before starting GSoC. With this information, KDE administrators designed together with us a classification schema for students' prior code contributions. Based on the average number of commits which are necessary for

the development of an add-on, a small application and everything beyond the following three categories have been created: low (0-3 commits), intermediate (4-94 commits) and high level of prior KDE development experience (> 94 commits).

Mailing lists are generally the preferred way to communicate in FLOSS projects. Using this form of communication, project contributors coordinate their coding efforts and help each other [18]. The time new developers have already been following the conversations on the project's mailing list hence indicates their familiarity with the existing values and group norms of the developer team. Moreover, the longer project novices have been following the conversations of the developer team, the more they are already known to the existing coordination and communication practices of the project group. Based on these indicators for novices' future working behavior, the time students were already subscribed to their project's mailing list is used as an objective measure for quantifying their supplementary fit, which is the first aspect necessary for **actual P-T fit**. To compute this period, GSoC students' first mailing list post was identified using markmail.org which also indexes all of KDE's more than 150 developer mailing lists. Students' first posts to subprojects which share a mailing list with other projects because of their size or interdependence have been identified with the help of KDE's administrators. Next, the timestamp of these mailing list posts was extracted and the resulting time difference (number of days) to the corresponding GSoC was calculated. To categorize this duration, project administrators from KDE helped us based on previous research in [44] creating the following schema: low (0-30 days), intermediate (31-180 days) and high level of prior conversational knowledge (>180 days).

Assessing complementary fit, students' suggestions and solutions to existing programming deficits in the corresponding subproject are considered relevant. Using their bug related interactions prior to GSoC, an

**Table 1: Kendal Tau's correlation coefficient**

	1	2	3	4	5	6	7	8
1. Project size	1	0.507**	0.656**	0.189*	-0.069	-0.073	0.143	0.002
2. No. of contributors		1	0.485**	0.136	-0.021	0.035	0.184*	0.019
3. Project age			1	0.152	-0.011	-0.073	0.140	0.102
4. Subjective assessment				1	0.184*	-0.162	-0.090	-0.072
5. Academic year					1	-0.055	0.005	0.035
6. Prior KDE contributions						1	0.488**	0.587**
7. Active days on mailing list							1	0.416**
8. Bug related interactions								1

\* =  $p < 0.05$ , \*\* =  $p < 0.01$

evaluation of students' distinct characteristics can be derived. To consider only students' prior interactions which were related to a particular program bug, KDE's bug management platform Bugzilla was mined. Counting students' message posts on this platform enabled us to quantify the number of their previous bug related interactions. To cover all related mailing list posts on this platform, Markmail's archive was queried for retrieving this relevant information. Again project administrators from the KDE project assisted us in designing the following schema to categorize students' distinct abilities. The three classes are: little (0-5 posts), intermediate (6-60 posts), and high (>60 posts) distinct skills.

Team members' **subjective assessment of P-J and P-T fit** is expressed through their prioritization of applicants' proposals. According to KDE's evaluation process of GSoC applicants, all team members of the corresponding subproject have to assign every GSoC application a priority number. This particular number is calculated based on a twofold evaluation. First, the mentor responsible for the proposed project looks at the applicants' competence and how the proposed project and its timeline fit to him or her. After this evaluation all project members are asked to vote for the applications based on their compatibility with the existing development and their value-added to the subproject. Based on these subjective assessments all GSoC proposals are rated with a prioritization number. Because this number is calculated considering both students' competence and their compatibility with the team, it is used in the following to measure team members' subjective assessment of P-J and P-T fit.

Students' **retention** behavior is considered in the following by the time they spent active in the project after their participation in GSoC. Consistent with

Colazo et al. this period is calculated by identifying students' latest commit for their chosen KDE subproject and the end of their corresponding GSoC event [6]. Based on querying markmail.org for the relevant commit data, a Bash script calculated the resulting retention period in days.

Project specific characteristics which have been found previously to affect FLOSS developers' retention behavior are its age, the number of active contributors, and the size of its codebase [6, 29]. To account for the effects of these factors, they are included as **control variables** in our analysis. The necessary information for KDE's subprojects have been collected using the online platform ohloh.net, which offers historical code statistics for all of KDE's subprojects

## 4.2 Hypothesis Testing

For the evaluation of our research hypotheses, three regression models explaining GSoC students' retention behavior have been designed and tested. The first model consists only of the control variables project age, size and the number of active contributors. In addition to these controls, the second model considers team members' subjective assessment of students' P-J and P-T fit. Evaluating the effects of students' prior development experience, team familiarity and distinct skills, 9 dichotomous variables have been constructed, representing the different levels of the three ordinal scaled variables. Based on reversed Helmert contrasts, the effects of each variable are then compared with the mean of the subsequent variable. In addition to these 9 dichotomous variables and the control variables, model 3 further incorporates the students' year of study to evaluate the effects of objective P-J and P-T fit.

**Table 2: Results of the three regression models**

	Model 1			Model 2			Model 3		
	B	SE	Sig.	B	SE	Sig.	B	SE	Sig.
Project size	0.000	0.000	0.374	0.000	0.000	0.142	0.000	0.000	0.106
No. of contributors	0.018	0.008	0.026	0.020	0.009	0.030	0.027	0.009	0.004
Project age	-0.001	0.004	0.759	-0.001	0.004	0.816	-0.002	0.004	0.663
Subjective assessment				0.135	0.069	0.051			
Academic year							-0.026	0.045	0.564
KDE low - med							-0.706	0.322	0.029
exp. med - high							-0.936	0.435	0.031
Team low - med							-0.845	0.348	0.015
exp. med - high							-1.037	0.330	0.002
Bug low - med							0.739	0.528	0.161
exp. med - high							0.019	0.460	0.967
	$\chi^2$								
		5.324			8.290			40.427	

An appropriate regression technique to analyze the effects and the predictability of these three models is the Cox proportional hazard model. This special regression technique allows us to investigate the simultaneous effects of several observed variables on the survival. The central element in this model is the hazard function which consists of the examined variables and describes the probability that an individual experiences an event at a given point in time. In our models this event describes the end of a student's project retention. The Cox regression model does not require this hazard function to follow any particular shape but only assumes that its influence over time is constant on the predicted variable.

With exception of eight students whose records could not be resolved in retrospect, our dataset includes data of all remaining 80 students who contributed to KDE during the last two GSoC events. 34 students took part in GSoC-2009 and 46 participated in GSoC-2010. Given the ordinal scale of some, Table 1 presents Kendal Tau's correlation coefficients for all used measures.

As detailed in Table 2, regression model 1, which consists exclusively of the control variables, explains the lowest variance compared to the other two models. Further, the analysis of the baseline model shows that only the number of existing contributors is significantly ( $p=0.026$ ) associated with retention. Contrary to existing FLOSS research, however, the number of existing contributors slightly increases ( $B = 0.018$ ) the risk that students discontinue their commitment after GSoC. The remaining controls have no significant association with students' retention. Incorporating team members' subjective assessment, regression model 2 explains more variance than model 1. Besides the number of active contributors ( $B=0.02$ ,  $p=0.03$ ), model 2 shows that students' subjective assessment is significantly associated ( $B=0.135$ ,  $p=0.051$ ) with retention. In line with KDE's descending prioritization schema the coefficient of subjective assessment indicates that students rated with a higher number are associated with a higher risk of leaving their subproject after GSoC. Testing the effect of actual fit, regression model 3 incorporates in addition to the students' year of study 9 dichotomous variables for their level of development experience, relational compatibility and distinct skills. Model 3 has the highest explanative power compared with the other two models ( $\chi^2=40.427$ ). In particular, it explains significantly more variance than regression model 2 suggesting that hypothesis 3 is supported with our data. According to the Cox regression in model 3, students' year of study is not significantly associated with the probability of them continuing their commitment to the corresponding KDE subprojects ( $p=0.564$ ). Beside the

number of active contributors, a strong and significant reduction in the risk of leaving the subproject, is associated with the level of students' practical experience ( $B= -0.706$ ,  $p=0.029$  comparing low and intermediate experienced students,  $B= -0.936$ ,  $p=0.031$  comparing intermediate and high levels of experience). Given the insignificant effects of students' academic education, our data only partially supports hypothesis 1. Further, Model 3 shows that the time students have already followed their subproject's mailing list strongly reduces the risk of them ending their contributions after GSoC ( $B=-0.845$ ,  $p=0.015$  comparing an intermediate with a low level of conversational knowledge, respectively  $B=-1.037$ ,  $p=0.002$  comparing high with intermediate level of conversational knowledge). However, the number of prior bug related interactions is not significantly associated with ongoing retention behavior ( $p=0.161$ , respectively  $p=0.967$ ). This suggests that our sample only partially supports hypothesis 2.

## 5. Discussion

The findings presented above offer important theoretical and practical implications. First, the results show that concepts from organizational recruitment can be successfully applied in the FLOSS context. Moreover, the sample demonstrates that the *objective* assessment of GSoC applicants' P-J and P-T fit predicts their future permanence at the corresponding KDE subproject much more accurate than the team members' *subjective* judgment. This finding supports our early findings in [38] and the observations in [3]. Emphasizing the importance of extracting objective key figures over the subjective assessment of developer retention, KDE's case could also be relevant for the general management of FLOSS initiatives. Future research is necessary to validate this assumption and examine whether there are other suitable figures to measure novices' actual P-J and P-T fit from the organizational perspective of a FLOSS project.

The correlations between the two P-J fit measures and developer retention support and extend existing literature. Consistent with previous research, students' level of practical development experience is strongly associated with their continued permanence. To ease interpretation, the regression coefficients are described in the following by their reduction in the risk that students leave their subprojects after GSoC ( $1-\exp(B)$ ). Compared to students with little experience, the risk of quitting is 50.6% lower for students with an intermediate level of development experience and 60.8% lower for highly experienced students compared to students with an intermediate level. These two associations between newcomers' level of development

experience and retention are in line with organizational research which emphasizes the effects of newcomers' level of relevant working experience on their future retention behavior. In addition, the associations support the theory of "situated learning" presented in [13]. Fang et al. argue that it is developers' eagerness to demonstrate their programming abilities which drives their future commitment to the project. Combined with this theory, our findings suggest that already an intermediate level of practical development experience is sufficient for novices' to demonstrate their skillset which in turn stimulates them to continue. Although our data support this assumption, further research is needed to validate the general use of previous FLOSS experience as a predictor for future project retention.

Contrary to our expectations, there is no significant association between students' academic education and their retention behavior. A possible explanation for this could be the used measure. According to Schmidt et al. not the quantity but the quality of education has to be considered for assessing newcomers' expertise [39]. Future research should address this and incorporate FLOSS developers' academic records for evaluating their coding expertise. Alternatively, other measures for newcomers' expertise have to be identified.

Besides students' technical competence, our study stresses the importance of their existing relationship with the project team for their retention. While the association between students' bug related interactions before GSoC and their retention behavior has been found insignificant, there is a strong association between the time they are following the project's mailing list and their continued project permanence. For students who followed the mailing list already for more than a month the risk of leaving is 57% lower compared to students who have only little knowledge of the exchanged mails between the team members. Moreover, in comparison to students with an intermediate level, the probability that students with a high level of conversational knowledge leave is 64.5% lower. These strong associations are in support of the socialization theory presented in [35]. Herein, Qureshi et al. describe that developers continue contributing because they socialize with the project's community. Combined with this theory, our data suggests that this socialization effect already influences developers who are following the project mailing list for more than a month in their retention behavior. However, to use novices' mailing list presence, as a general indicator for their project permanence, future research is needed.

Surprisingly, our analysis found no significant association between students' amount of bug related interactions prior to GSoC and their future retention behavior. Following organizational research, a strong association was expected. An explanation for this

could be the used measure. Maybe not the quantity but the quality of bug related interactions has to be considered for assessing complementary fit. Future research should test this by applying text analysis on newcomers' prior bug related interactions. An alternative explanation for this insignificant association is that KDE's developer community respects and appreciates developers who contribute new code more than team members who fix existing program deficits. Consequently, newcomers show their complementary characteristics rather in form of new functionality than in fixing existing program deficits. Both explanations need further examination in future research to understand the found insignificance between students' bug fixing behavior and their project retention.

## 6. Limitations

Our research has several limitations. First, our data encompasses only the retention behavior of former GSoC students at KDE. Consequently, it might not be representative for other FLOSS projects. In addition, the monetary rewards students' receive during GSoC might cause a higher extrinsic motivation than is typically expected of newcomers to FLOSS projects. This level of higher extrinsic motivation may be stimulated further by the awareness of the GSoC and Google in general within the FLOSS community. Finally, only 732 days have passed since the end of GSoC-09 and 371 since the end of GSoC-10 and the latest KDE commit which we could have possibly collected. These periods, mark the upper limit for project retention which could be measured for GSoC students.

## 7. Conclusion

The identification of contributors who are likely to remain is of special importance for the future of FLOSS projects. It enables the existing developers to concentrate their training efforts on newcomers who are likely to remain in the project. Previous research shows that individuals' subjective assessment is often inaccurate emphasizing the use of objective fit measures to identify sustained developers early on [3, 38]. In this paper we detail how concepts from recruitment literature can be applied to assist team members with the identification of long-term contributors early on and evaluated their accuracy. Based on the retention behavior of 80 former GSoC students, we reveal that P-J and P-T fit are two concepts that are suited to predict developer permanence in FLOSS projects. As described by P-J fit, students' level of relevant development experience is strongly associated with their project retention after



the event. Consistent with P-T fit, we detected that students' familiarity with the coordination practices of the project team has a strong association with the time they spend on their projects after GSoC. Contrary to our expectations, our data suggests that students with skills that have been underrepresented in the team and students with a higher academic education do not remain considerably longer in the project.

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