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Cultural Diversity and the Performance of Student Software Engineering Teams

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Abstract. We investigate the impact of cultural diversity on short-lived student teams who develop software in an educational setting. The aim is to determine whether there is a correlation between the cultural diversity of software development teams and the success of these teams. Cultural diversity is measured in terms of the variety of languages spoken by the team members and their ethnic differences. The team's success is measured in terms of the quality of the software project they produce as well as the extent of the collaboration in the team while working on the project. The purpose of the study is to gain insight into how cultural diversity affects the success of the teams. We conclude that the cultural diversity of teams has no observable effect on the success or failure of short-lived student teams in a software development project.

1 Introduction

Software projects often fail. Gupta et al. [11] state that between 50% and 80% of information systems projects fail. This high failure rate of software projects has led to intensive research on mitigating the failure of software projects [17]. It is commonly believed that team members' competence in "hard skills" plays an important role in project success, but a recent study of workplace success (surprisingly from a company most identified with science, technology and engineering – google) contradicts this conventional wisdom [29]. This is, however, not groundbreaking. For many years one of the reasons for failure which is often cited is human factors [17,22]. A project may fail as a consequence of the team's failure to collaborate [28].

When constructing and managing software development teams from culturally diverse backgrounds, it is important to guide the members to understand and appreciate cultural differences in order to avoid any misunderstanding arising from these differences [13,14].

The current literature is dominated by studies conducted in other countries [15,19,32]. There is little research reported on cultural differences in software engineering in Africa. The aim of the present study is to attempt to address this shortcoming.

Cultural diversity is prominent South Africa. Terms such as racism and xenophobia are often heard on the local news and used in conversation. A deeper understanding is needed of the role of cultural diversity in the workplace to provide a sound scientific foundation for project management in this environment.

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Proceedings of the 47th Annual Conference of the Southern African Computer Lecturers' Association (SACLA 2018)

ISBN 978-0-720-80192-8

We believe that cultural diversity can positively contribute to the quality of work done by teams and might also lead to better team cohesion in spite of the logical arguments that language barriers are likely to cause communication problems and that differences in beliefs and morals may lead to diminished trust. The current research investigates these claims.

We conducted research specific to student teams performing software engineering tasks in tertiary education in a South African context. We envisioned that if we would identify trends in the relations between cultural diversity measures and the performance of our teams, that the findings may be applicable to student teams doing tasks not necessarily related to software engineering.

2 Literature Survey

2.1 Defining Culture and Diversity

Culture can be defined as a certain mental programming [7,14] that is learned by every individual since childhood [6,14] from the social environments [14,31] into which the child was born. This mental programming can be conceived as the symbols [14,31], the basis of each individual's values [6,8,9,14,27] and the norms [31,27] that guide the way that individuals behave [31,27,8] and think [27,7,8,14]. Hofstede et al. [14] state that even though culture is perceived by the public by means of actions, rituals and symbols, the significance of these are known only by the individuals who share the same cultural history.

Many researchers have studied how diversity in software development groups influences the effectiveness and eventual success of a project. Some reports highlight the positive aspects of such team compositions while others mention disadvantages to composing culturally diverse software development teams. Section 2.2 discusses some advantages of composing teams with a culturally diverse background and Section 2.3 points out some disadvantages of doing so.

2.2 Advantages of Cultural Diversity

It has been reported that teams that are culturally diverse more likely to be effective and successful in creative tasks [8,12,10]. The different views [31] of the individual team members in culturally diverse teams may encourage better reasoning and decision making about the software tasks [12,31,8], enhance the members' innovative skills [8,3] and promote learning [31,10]. Extensive cultural differences in software teams are also helpful for examining more options for system design options because individuals have different priorities [16].

2.3 Disadvantages of cultural diversity

Differences among individuals' beliefs, values, attitudes, and perceptions may inadvertently cause conflict [18,10,22]. Conflict in culturally heterogeneous teams can be

difficult to manage, since each individual may have different priorities [16], views of relevance [31] and interpretations of requirements [6]. Furthermore, language barriers may inhibit satisfactory communication among team members [17,18]. Poor communication in teams leads in turn to diminished trust [10] which hinders individual performance and overall team effectiveness.

3 Problem Statement

3.1 Problem

Students enrolling for a Computer Science degree at the University of Pretoria are culturally diverse. They have different backgrounds, beliefs and morals. We are interested to know to what extent cultural diversity effects the performance of teams in our setting.

3.2 Objectives

It may be difficult to attain clarity about the problem stated in Section 3.1. Culture is in itself a complicated topic, and when combining it with the complexity of defining whether or not software development teams are successful, the resulting problem is wicked [4,5]. For this reason, this research defines cultural diversity only in terms of two aspects as described in Section 5.4. We also limit the study to determine the effect of cultural diversity on only two aspects of team success. The study is thus limited to only the following objectives in terms of our definition of cultural diversity:

- To assess whether culturally diverse software development teams produce better work than culturally homogeneous teams.
- To assess whether culturally diverse software development teams produce better work than culturally homogeneous teams.

This research observes these aspects only in short-lived teams who participated in a series of micro projects discussed in Section 4.

4 Setting

The software engineering capstone module is compulsory for the Computer Science degree offered at the Department of Computer Science at the University of Pretoria. During the first eight to ten weeks of the module, students are required to complete a series of four micro projects in different teams. New teams are assigned for each micro project. The different micro projects build on each other to constitute the design, implementation and testing of a single, fairly large, software product comparable to a real-world software product. The micro projects are, however, small and well-defined teaching assignments [23]. The students are expected to learn how to use technologies and tools needed in software development and project management and at the same time to develop the soft skills needed to implement large systems of this kind [20,21].

5 Method

5.1 Data Collection

Data was gathered in the period 2011–2016. It included information about a total of 434 students who were assigned to a total of 246 differently composed teams.

The following information was obtained from student records maintained by the university's registration office:

- The ethnicity of each individual.
- The home language of each individual.
- The individual's marks for passed modules.

Scores were calculated regarding the ability of the students and their participation in their teams.

An ability score for each individual is calculated based on his/her performance in the prerequisite modules for the capstone module. This measure is used based on positive correlations between compliance with admission requirements for a module or programme and success which have been established through empiric research [25,26].

The participation of students in their teams were obtained by analysing the responses to the peer reviews after each micro project. We used the levels defined by Pieterse et al. [24] shown in Table 3. The students were expected to complete a peer review after finishing each of their micro-projects. In each review they were asked to reflect on how they perceived themselves and how their peers perceived them. The questions that the students had to answer guided them to reflect on their own contributions and also on the contributions of the other members. These questions were the same as those used by Pieterse et al [23]. The same questions were asked in all peer assessments. The participatory level of each of the students in the team was determined through the analysis of the answers students provided in these peer reviews for each micro-project team.

In a given year, each student in the class was assigned to a different team for each of four micro projects. This gave us 246 differently composed teams that we could study. For each of the teams the following information was compiled:

- A mark to evaluate the quality and correctness of the artefact that the team produced. This mark was assigned by the teaching staff.
- A team ability score based on the ability score of each individual.
- A team cohesion score based on the participatory ratings of the individuals in the team.

5.2 Data Processing

The anonymous student data for the individuals in each team was grouped to form a data set for each team. Typically, a student's data would be duplicated in the different data sets for all the teams in which he/she participated.

The data about each individual in each team was used to determine measures to describe the team in which the individual participated. Teams were excluded in cases

where we did not have enough information about the individuals in these teams, or where we did not have access to the marks that had been assigned to the team's deliverables.

5.3 Participants

Table 1 summarises the attributes of the students who were observed.

Table 1. Profile of individuals

Number of males	345
Number of females	81
Total number of individuals	426
Number of languages	17
Number of ethnic groups	4

Figure 1 shows the number of individuals included in this research by gender and ethnic group and Figure 2 shows the number of individuals included in this research by first language. Those counted as “Afr/Eng” stated that they were equally fluent in Afrikaans and in English. Nguni includes IsiNdebele, IsiXhosa, IsiZulu and SiSwati. Sotho includes Sepedi, Sesotho and Setswana. Those counted as “Other” are international students whose first language is French, German, Polish, Portuguese, Russian, etc. Apart from being fluent in their first language, all the students should be fluent in English.

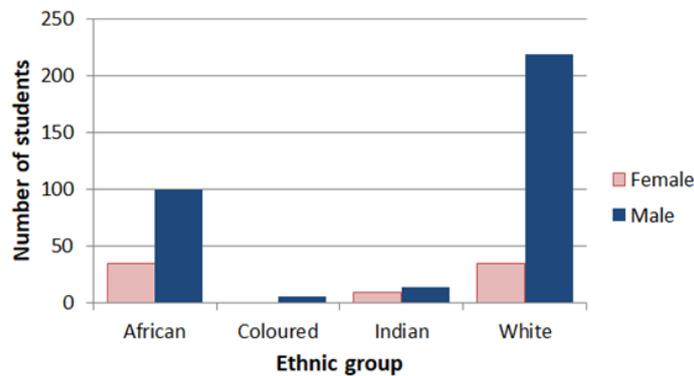


Fig. 1. Ethnicity and gender (n=426).

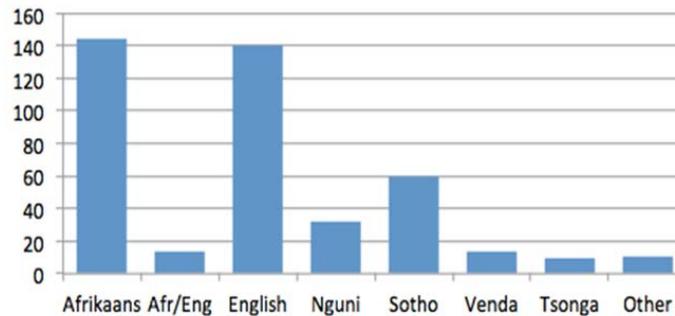


Fig. 2. Languages (n=426).

Quantifying Cultural Diversity

Diversity is defined as any difference (age, race, culture, etc.) that distinguishes individuals from one another [17,27]. This research considered only the national cultural diversity within a software development team. All other diversifying factors were ignored.

The diversity of a team is calculated by means of the following team member attributes:

- Team's ethnic composition
- Team's language composition

Ethnic Diversity. The ethnic diversity score of a team is expressed in terms of the ratio of the team members who belong ethnic groups other than in the largest ethnic group in the team. For example, if a team consists of 2 White, 0 Coloured, 1 Indian and 4 African members, the ratios for the four ethnic groups are $2/7$, $0/7$, $1/7$ and $4/7$. The ethnic diversity score for this team excludes the ratio for the majority group (the Africans). It is therefore $3/7 = 42.85\%$. The ethnic diversity distribution within teams as shown in Figure 3 indicates that the majority of teams in our investigation had low ethnic diversity scores.

Language Diversity. The language diversity score was calculated by counting the distinct languages spoken as first language by the members in a certain team, dividing this value by the number of individual members in the same team, and then multiplied by 100 to get a percentage score. Figure 4 illustrates that the distribution of languages in the various teams is fairly balanced.

The ethnic diversity score as well as the language diversity score are each used to investigate if there is any correlation between the diversity of the software team members and the success of a project.

Table 2 shows the descriptive statistics of the data about the diversity in the teams observed in the research.

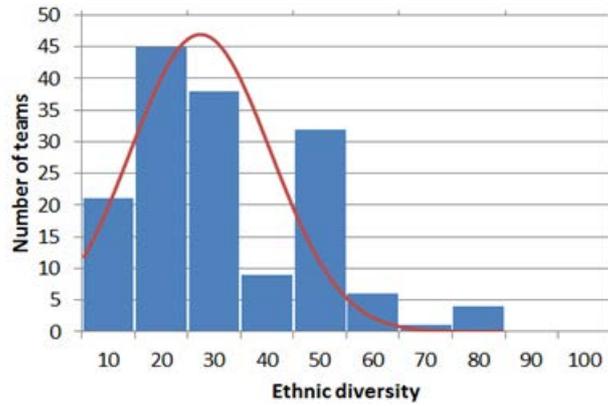


Fig. 3. Distribution of ethnic diversity scores.

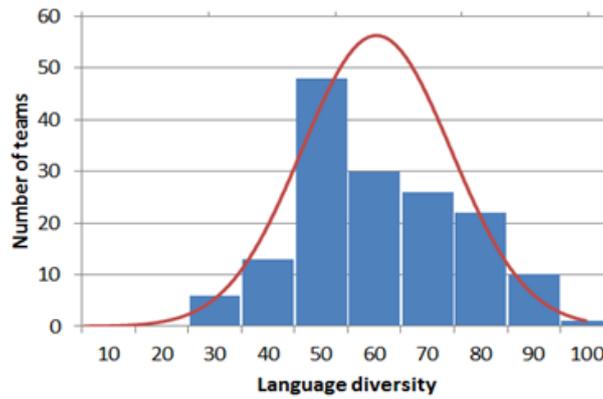


Fig. 4. Distribution of Language Diversity Scores.

Table 2. Descriptive statistics of team diversity data.

Number of distinctive teams	156
Average number of individuals in a team	7
Ethnic diversity score – mean	27.48%
Ethnic diversity score – standard deviation	16.57
Language diversity score – mean	57.59%
Language diversity score – standard deviation	14.73

5.4 Quantifying Project Success

Baccarini [2] defines project success in terms of two separate components, namely project management success and project product success. Management success includes successful team accomplishments regarding collaboration, cost and time [1] whereas product success focuses on the functionality and quality of end product [30].

In this research, success is defined only in terms of a measurement of team cohesion and a single measurement of the scope, functionality and quality of the product. Other criteria for project success, such as cost and time to market, were not considered. The success was calculated by means of the following attributes described in more detail in the remainder of this section:

- Normalised work quality
- Team cohesion

Work Quality. The work quality of each micro project team was measured in terms of the marks allocated during the summative assessment of the team deliverables. The lecturing staff evaluated the deliverables of each team. The marks awarded to each team were used as a measure of the quality and correctness of the artefact produced by the team.

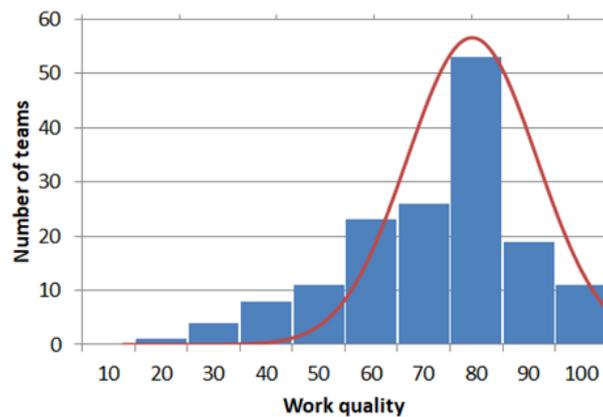


Fig. 5. Distribution of work quality scores

A team ability score is calculated for each team. This score quantifies the competence of the team, based on the average of a measure of the ability scores of the members in the team discussed in Section 5.1. The normalised work quality was calculated by applying standard statistical score normalisation to normalise the marks for the deliverable according to the team's ability score.

The distribution of the normalised work quality, shown in Figure 5, indicates that quality of the artefacts produced by the students was according to expectation.

Team Cohesion. We deemed team cohesion to be important for successful software development. For this reason, we derived a metric to quantify team cohesion in terms of a team's participation success score to represent the software project-management aspect of project success in our context.

We determined a score to represent team cohesion, based on the participation level of each student in each team, which was established as described in Section 5.1. We

attributed scores to each of the participatory levels shown in Table 3. These scores were selected on the basis of a theoretically preferential team composition of (teams that work well together).

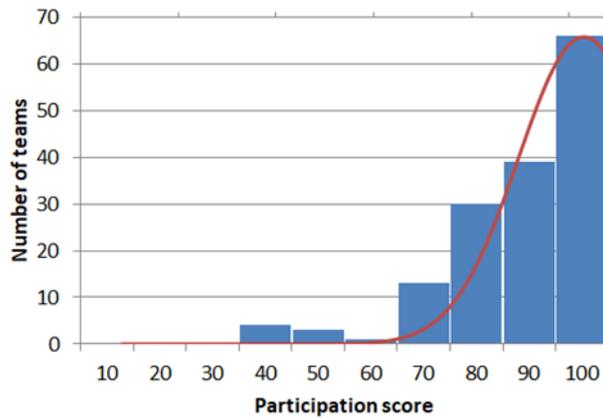


Fig. 6. Distribution of team cohesion scores.

Table 3. Description and scores for participation.

Level	Description	Score
Insightful Shaper	A successful leader who manages to motivate and allow the other team members to participate.	3
Compliant Worker	A member who is relatively unquestioning and likely to accept the decisions of others without consideration, yet usually does what is expected of him or her.	3
Diligent Isolate	A member who willingly increases his/her effort when working in a team, not only to complete his/her own tasks exceptionally well but also to redo or improve the work of other members.	2
Social Loafer	A member whose contribution is perceived to be inferior to that of others in the team.	1

A score was given to each individual in each team, based on the participation level scores. The scores of each individual in the team were added together and divided by the maximum score that the team could possibly achieve (i.e. $3 \times$ number of members in the team). As shown in Figure 6, the team in general had very high team cohesion.

Table 4. Descriptive statistics of project success data.

Number of distinctive teams	156
Average number of individuals in a team	7
Normalised work quality – mean	68.65%
Normalised work quality – standard deviation	16.48
Team cohesion – mean	84.35%
Team cohesion – standard deviation	14.72

Table 4 shows the descriptive statistics of the data related to the success measurements defined in this section.

6 Findings

We used scatter plots to investigate the influence of each type of diversity (language and ethnic) on each measure of team success (quality and cohesion). Table 5 shows the linear regression models for each of the four possibilities while Table 6 shows the goodness of fit (R^2) for each of these possibilities. The R^2 values are very small (<0.03). This upper bound of the R^2 values in this table is ten times smaller than the smallest value, which may indicate that variation in success could be explained by the variation in diversity. It is evident that the null hypothesis, namely that there is no correlation, could not be rejected in all cases.

We show and discuss only two of the four scatter plots as representative ex-amples of the rest of these scatter plots. The chosen scatter plots are those with the highest variation.

Table 5. Causal regression models.

	Quality	Cohesion
Language diversity	$y = -0.1182x + 75.469$	$y = 0.0237x + 82.986$
Ethnic diversity	$y = +0.0115x + 68.344$	$y = 0.1452x + 80.363$

Table 6. Goodness of fit (R^2) of the regression models.

	Quality	Cohesion
Language diversity	0.0112	0.0006
Ethnic diversity	0.0001	0.0267

When looking at the equations defining possible regression models, the largest positive slope is in the model describing the impact of ethnic diversity on team cohesion. Figure 7 shows the scatter plot for this case. The regression line has a very slight upward slope. There seems to be a minute increase in team cohesion as the ethnic diversity of the team increases. Team work in general is considered to be a communication-intensive action and therefore suggests that success could depend on good communication among team members. This positive slope may imply that ethnic diversity in a team has a positive impact on how well the individuals in the team work together, i.e., team cohesion increases as the team's ethnic diversity increases. This is, however, counter-intuitive. Ethnic diversity is likely to have a negative impact on communication and understanding, which may in turn lead to lower levels of team cohesion. This anomaly can be explained by the low variation in the team cohesion measures in our data.

The increase in team cohesion which correlates with the increase in the ethnic diversity is practically zero. It can therefore be concluded that the ethnic diversity in teams seems to have no impact on how well the members in these teams cooperated.

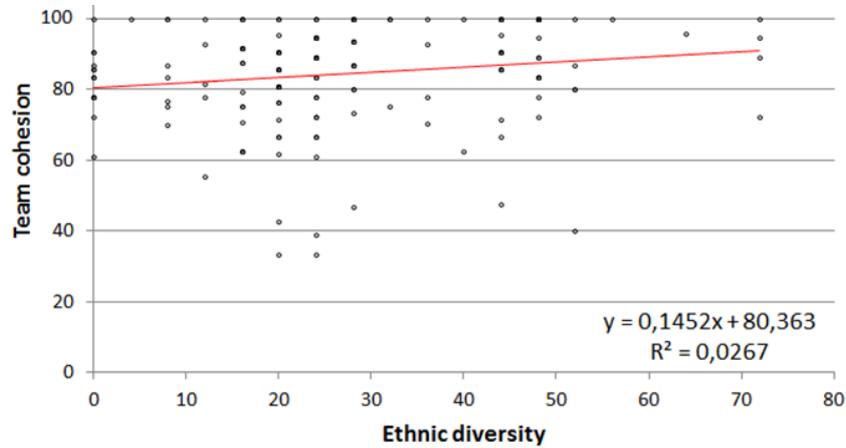


Fig. 7. Correlation between ethnic diversity and team cohesion.

The largest negative slope is in the model describing the impact of language diversity on the quality of the team deliverables. Figure 8 shows the scatter plot for this case. The regression line has a very slight downward slope. This could be interpreted as indicative of the negative impact of language diversity on the quality of the work done by the team. Once again, the slope is practically zero and the goodness of fit is insignificant. The null hypothesis of no correlation between these measures can thus not be rejected.

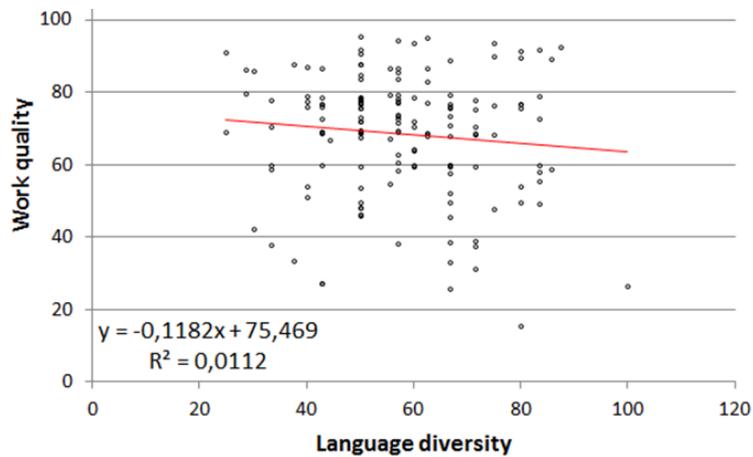


Fig. 8. Correlation between language diversity and work quality.

Since the data is clearly not normally distributed, and therefore not really amenable to conventional parametric correlation tests, it was decided to investigate whether the well-known Spearman's rank correlation test would reveal anything different. The correlation between the three different diversity measures and the two different measures

of success. The results are shown in Table 7. In all cases, these coefficients again confirm that the null hypothesis of no correlation could not be rejected.

Table 7. Spearman's correlation coefficients.

	Quality	Cohesion
Language diversity	-0.1000	0.0761
Ethnic diversity	-0.0055	0.2272

We have therefore found no evidence that could lead us to believe that our measures of team diversity have any influence on the success or failure of a project defined in terms of the work quality or defined in terms of our measure of team cohesion.

7 Limitations

It may prove challenging to generalise the findings of this research to (i) real software development in a working environment, (ii) long-lived teams and (iii) teams performing non-SE tasks, owing to the following limitations of the research:

- Teams had to perform only the tasks required during software development.
- Teams for the research were chosen only from a single institution in a specific module setting.
- Most participants were male students in the age group 19–22 years.
- Teams were short-lived (two to four weeks).
- Teams were assigned by the lecturer.
- Teams were relatively large (five to eight members).
- Projects were relatively small and well-defined (teaching assignment vs. real-world projects).
- The success of the teams was measured by means of subjective observations.
- Real-world criteria such as cost and time to market were not considered.

8 Conclusion

We summarise the advantages and disadvantages of having culturally diverse teams. Educators should take cognisance of how cultural diversity may influence the classroom situation when students are required to work in teams.

We described how we teach the software engineering process by means of a hands-on series of micro projects which involve the students in the design and implementation of a software product of real-world style. This brief description and pointers to other publications about this method of teaching may enlighten educators who are involved in similar courses.

We described the techniques we employed to gather information and quantify the team attributes. We defined metrics to measure aspects of cultural diversity in teams as

well as metrics for measuring team success in our context. These are based on accepted beliefs about these concepts.

We applied statistical methods to investigate correlations between the aspects of cultural diversity of teams and two measures of project success. In corroboration with criticisms by other authors [10,17,18], we originally hypothesized that cultural diversity in a software development team would dramatically decrease the communication among individuals in the team. Our research results show that this hypothesis is incorrect in our context. The results in fact show that, there is a slight possibility that an ethnically diverse team may be more cohesive than an ethnically homogeneous team. The contradictory results are not conclusive. It might be specific to the situation, so the results should be interpreted with extreme caution.

The research conducted and reported on in this paper, which was originally inspired by the research done by Hofstede et al. [14], accords with the research of other researchers such as Bradley and Hebert [3], Deshpande et al [8] and Walsham [31] that, although there may be managerial complications when composing culturally diverse software development teams, there is no reason to believe that culturally diverse teams will be worse off than culturally homogeneous teams.

Our research, however, did not corroborate the findings of other researchers who have indicated benefits [8,12,10] and drawbacks [18,10,16] of having culturally diverse teams. Instead, our research results suggest that the performance of our teams is not influenced by the cultural diversity of our teams. The observation that claims regarding cultural diversity of teams may not be applicable in our context confirms an alternate view that there is no critical need to ensure or to avoid cultural diversity in our teams.

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