Challenges for Inclusion in Software Engineering: The Case of the Emerging Papua New Guinean Society

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***Abstract*—Software plays a central role in modern societies, with its high economic value and potential for advancing societal change. In this paper, we characterise challenges and opportunities for a country progressing towards entering the global software industry, focusing on Papua New Guinea (PNG). We conducted a qualitative study by employing a questionnaire (n=52), recording talks (n=3) and discussion in a workshop we organized, and administering an in-depth focus group session with local actors (n=5). Based on a thematic analysis, we identified challenges for the PNG software engineering community. We also discuss best inclusive practices that target practitioners, researchers, and educators from both the local and global software engineering community.**

I. Introduction

Advances in technology have the potential to transform societies [1]. As a society currently undergoing technological, economic, and social transformations, Papua New Guinea (PNG) is entering the digital age and showing signs of an emerging local software engineering community. In 2018, a local PNG software development team won the annual APEC App Challenge [2]. Such progress paves the way for local economic development, with opportunities for young and talented individuals to develop software in areas such as natural resources, finance, healthcare, and education. These developments also open the local society to the global software engineering (SE).

Following the work by Reijswoud et al. [3] carried out in 2009, we set out to conduct a qualitative study with local community in PNG, exploring the current situation and possible future directions in that emerging software development society. We organised a workshop [4] in PNG and conducted an empirical analysis based on three recorded talks, 52 questionnaire responses, and a focus group session with five participants. Through thematic analysis, we derived five themes that affect software engineering in emerging societies such as PNG. From that analysis, we distilled a set of local as well as global implications.

II. Papua New Guinea as an Emerging Society

As an emerging society, PNG's population is young and growing. The country's economy is currently dominated by resource-driven sectors, such as agricultural, forestry, and fishing sectors and the minerals and energy extraction sector. PNG's emergence into the digital age may foster access to life-enhancing services in areas such as health and education. It may also catalyze innovation and economic growth, with the promise of new jobs and increased tax revenues [5]. Like other emerging nations, PNG's Internet connectivity remains comparatively low, but is continuously improving. From 2010 until 2013, the Internet penetration increased from 1.3% to 6.5%. Since 2013, Internet penetration has increased from 6.5% to 11.7% in 2016. This penetration is, however, significantly lower than in the neighbouring countries of Indonesia (54.7% in 2017) and Fiji (46.8% in 2017) [5]. This situation is about to improve with a new submarine fibre-optic cable connection to Australia [6]. Recent developments have seen initiatives such as the PNG digital Information Communication and Technology Cluster Association [7], founded by young local software engineering Small to Medium Enterprises (SMEs). The PNG

Table I
Demographics of survey participants

Demographic	# Respondents
High School Students	23
Professionals	12
Startup associates	10
University Students	7
TOTAL	52

Table II
Demographics of invited speakers (S1-S3) and participants in the focus group (P1-P5)

ID	Gender	Demographic	Sector
S1	Male	Business Officer	State-owned Enterprise
S2	Male	Chief Executive Officer	Government Organization
S3	Female	Project Manager	Financial Institution
P1	Female	Managerial (IT)	Financial Institution
P2	Male	Managerial (Non-IT)	Corporation
P3	Female	University Student	Public University
P4	Female	Entrepreneur (CEO)	Local Startup Company
P5	Male	IT Consultant	Financial Institution

Table III
QUESTIONS FROM THE SURVEY

	Survey Questions
Background	What is your current role and affiliation? Have you ever worked on a closed-source software project? Have you ever worked on an open-source software project? If you have contributed to open-source before and how did you choose which project to contribute? Have you spent time outside of PNG for education or work? If so, where and for how long? What attracted you to attend this workshop?
Programming and Software Development Education	What formal education have you had in programming and/or software development? If you had any education in programming/software development, what motivated you to learn? Where did/do you learn programming/software development outside of formal education? What do you see as the main strengths of programming/software development education in PNG? What do you see as the main challenges for programming/software development education in PNG, what would it be? If you could change one thing about programming/software development education in PNG, what would it be?
Tools and Infrastructure	What tools do you use when developing software? Where and how did/do you find these tools? How do you keep up with the latest trends and developments relevant to software development? If you could change one thing about tools/infrastructure for software development in PNG, what would it be?
Outlook	In your opinion, what is the role of programming and software development for industry and society in PNG? What do you think will be the most important trends in programming and software development for PNG in the next few years? Would you be willing to have a quick follow-up chat with us? How can we reach you?

Table IV
QUESTIONS THAT GUIDED THE FOCUS GROUP DISCUSSION

	Focus Group Questions
Market/Hiring	How is the software market? What are the opportunities? (languages and platforms etc.) What kind of recognition would be interesting after training people? When you hire someone, what kinds of evidence do you request to understand the skills and abilities of the candidates? Would you consider looking at the GitHub profile? How to create awareness about what is possible to learn/work with/do with software development?
Infrastructure	How common is it to have computers at home/school/freely accessible? If available somewhere, what is the pre-set of applications? Who should be responsible to lead some kind of project? Should it be inside existing high schools, universities, etc.?
Education/Training	How should education be adapted? University vs. school level? When do they start teaching programming? When should they start? How do developers learn to code? (since the internet connection is unstable, copy and paste may be less common) What about mentoring? Who would be a mentor? How would mentors be recruited? How would mentors be trained? Where on the Internet do you look for information about software development?
Government	How do you feel that politics and government act in terms of supporting software development initiatives? What do you need from the government to help promote the field?

government has also begun to invest in SMEs to advocate for financial inclusion [8]. Those SMEs, together with students and software engineering professionals that manage the local computer networks and software systems both in government bodies and private businesses, form the local SE community.

A. The Software Engineering Perspective: BRIDGES 2019

To achieve our goals of describing the current state of software engineering in PNG along with challenges and potential solutions in education, industry, and the broader society, we conducted a qualitative study involving local actors from the emerging local software engineering community. To this end, we organized and hosted the International Workshop on BRIdging the Divides with Globally Engineered Software (BRIDGES). The workshop was held for three days in Port Moresby, the capital city of PNG and the largest city in the Pacific region. It was designed as a forum to encourage the exchange of ideas between the local and international software engineering community. This included invited talks by both local and international participants as well as extensive discussions. The workshop was supported by industry, government bodies, the University of Papua New Guinea (UPNG), and Nara Institute of Science and Technology (NAIST). The co-authors of this paper were either involved in the organisation of the workshop or contributed as invited international participants.

III. STUDY DESIGN

The empirical results presented in this paper are grounded in three data sources.:

1) *Questionnaire-based Survey (n=52):* Table III outlines the structure of the questionnaire we handed out to all

workshop participants and to the participants of a startup meetup on the same day. The questionnaire was composed of workshop participants' demographics and their perceptions related to education, tools and infrastructure.

2) *Workshop Talks (n=3):* Workshop talks given by local SE community members were recorded (see Table II). All three talks ranged from 25 to 30 minutes and included interactive discussions with the audience afterwards. The invited talks and related discussions covered a broad range of perspectives, including government (S2), industry (S3), and local infrastructure (S1).
3) *Focus Group Discussion (n=5):* A preliminary analysis of the survey responses and workshop talks informed the questions we used during the semi-structured focus group session (see Table IV). The participants for that session were recruited from workshop participants, incorporating diverse backgrounds and perspectives (professional and student men and women, working in management and consulting, from IT and non-IT fields, and in large companies and startups). The in-depth focus group "round table" discussion took place two days after we collected the survey responses.

Those data sources are connected, since emerging patterns we noticed after attending the talks and conducting a preliminary analysis of the survey responses informed our interview guidelines for the semi-structured focus group.

Table I and Table II show the diverse demographics of our participants, which included students and professionals, men and women, and representatives from multiple sectors, and with multiple roles. We conducted an in-depth qualitative analysis based on the survey answers and our recordings of the talks, the subsequent discussion, and the focus group session. Following recent work [9], we structured our analysis of the collected data based on the thematic analysis framework proposed by Braun and Clarke [10]. The initial coding started with the analysis of the focus group, resulting in a total of 79 codes, including codes such as "not enough developers and designers" and "outside of Port Moresby, most education related to computers and IT is theory." This analysis was later merged with and reinforced by the codes generated from the questionnaire responses and the workshop talks. The first four authors collaboratively conducted the first round of analysis. The remaining three authors were used as validity checks to ensure that the analysis was consistent throughout the process.

IV. Findings

A. Themes

Table V summarises the themes which emerged from our analysis, together with the number of codes and number of focus group participants which contributed to each theme. As the table shows, each theme relates to codes that were assigned to quotes from at least three of the five focus group participants. An additional eight codes from the original annotation were used to inform the discussion of implications, cf. Section V. Each theme was further augmented with data from the analysis of the survey responses and talks. We identified the following themes as challenges for the PNG SE community.

Table V
Themes which emerged from the data analysis

Theme	# Participants	# Codes
Market focused on customising off-the-shelf	4	29
Early stages of technological leapfrogging	3	4
Limited dedicated SE training	4	25
Investment potential in local SE	4	9
Establish trust in local SE	3	4

a) ***Market focused on customising off-the-shelf software****:* As a result of limited capacity as well as company and government policies to buy off-the-shelf software, the market for software developers in PNG is relatively small and provides more opportunities for customisation than developing software from scratch:

> *"A lot of the bigger companies [...] buy off-the-shelf products. [...] The products are normally standard off-the-shelf, and then they would be customised, but usually the vendor would provide the software development to the company; and the in-house software development team would have very minimal software development. They would most likely develop the intranet for the internal company or the website." –P1*

Overseas companies, often from nearby Australia, are attempting to fill this gap, but this comes with costs related to software security, for example:

> *"Most of the technology companies that do come in—most of the tenders for many of these large projects, not just large projects, but any sort of custom software development project—are overseas. There's a lack of local capacities, and support and maintenance are provided by those companies offshore as well. [...] Security is a big issue. If people in the company don't understand how the system is built, especially if it's a custom one, then you never know how the system is properly protected." –P4*

While this could create a potential for the local software development market, such potential often remains untapped, and even startups focus on the customisation of existing technologies:

> *"So the opportunity is for us to develop it based on our rules or the way we do business, but because we don't have enough software developers or designers, we can't be able to design systems that are fit for purpose." –P1*

b) ***Early stages of technological leapfrogging****:* Technological leapfrogging refers to the transit of countries from the condition of relative underdevelopment to that of an advanced industrial and technological state in a relatively short span of time [11]. This process typically follows three steps: (1) importing and absorbing highly modern technology, (2) replicating, producing, and improving the imported technology, and (3) moving on to innovations on one's own. Our data suggest that PNG currently finds itself at the early stages of such technological leapfrogging.

> *"Education is a big a thing. In PNG, amongst average Papua New Guineans, their idea of technology is just the Internet or Facebook or whatever they use." –P4*

To move further along the path to technological leapfrogging will require improved digital technology and digital literacy, as evidenced by this anecdote from one of our focus group participants:

> *"Last year, when I was in another province of PNG, we ran a one week workshop for girls in ICT there. So we got girls from throughout that province from the high schools. And there were about 25 girls and three of the girls that attended had never touched a computer before. And they were literally scared to touch a computer because they thought they would break something. So not everyone has access to digital technology. [...] So access to digital technology is one, and then digital literacy is another thing." –P4*

A side effect of limited digital literacy is the tendency to try to run before one can crawl, e.g., by investing in the latest technologies despite a lack of foundational knowledge and experience.

Investments into the latest technologies do not necessarily trickle down to the software engineering community:

> *"A lot of our CEOs are traveling overseas, and they're reading a lot of these in-flight magazines. So there's a lot of content on Blockchain. So right now there's so much money being pumped in here to bring Blockchain software developers into the country. [...] But it's not being translated down, we don't understand how we could use Blockchain when the Internet's not that good, and we don't have the software engineering community." –P1*

A large barrier that is frequently mentioned in the talks, the survey responses, and the focus group is the high cost and low speed of the Internet infrastructure. Mobile Internet access, which is most commonly used, costs around 150 Papua New Guinean Kina per month (approx. US$45) for 30GB, unlimited access costs around 850 Kina per month (approx. US$250). Participants pointed to the general potential of "open source software" and "learning online".

> *"There is no point in building a big highway (internet cable), [when] there are no cars (applications) to ride on that highway. We hope this workshop can give our people incentive to build software to put the cars on this road. We hope our people can build software that puts traffic on what we are building." –S1*

S1 belongs to the state-owned entity that has been commissioned by the government to build a fibre-based network that will connect all 22 provinces across PNG, enabling the implementation of data centers that are expected to benefit the business, education, and healthcare sectors.

c) ***Limited software engineering training****:* With an adult literacy rate of 63.4% as of 2015 [12], education unsurprisingly plays a large role in the advancement of PNG as an emerging society. The needs around software development education were summarised by one of our focus group participants as follows:

> *"I think we need specialised skills. From a graduate perspective, when we come out of uni, we only know the basics, we learn the general stuff—networking and programming, everything [...] From where I'm working now, there are IT people in the organisation, but I think they lack the specialised skill in software engineering so they can support the organisation and build something, build a system, instead of just the general knowledge of everything." –P3*

In the survey, we asked participants about one thing they would change regarding software development education in PNG. Six professionals mentioned changing the education system either by teaching coding early (in primary or high school) or by offering higher-education courses dedicated to software development. Researchers and practitioners should be involved in designing an updated curriculum:

> *"It's just they're learning stuff that's not up-to-date to where the industry is today. The other thing is, a research-backed and industry-backed curriculum that's developed so that when our students graduate, they go out with the skills that are relevant to the world today." –P4*

In an emerging society that has only recently reached the new frontiers of the digital age due to its developing education base, finding mentors within the country is challenging:

> *"Nobody's done it before us. Without mentors, everything is pioneering, it's the first time." –P1*

Participants mentioned several online education websites, including FreeCodeCamp, O'Reilly, Udacity, and Coursera, which can serve as a substitute for formal education in some situations.

d) ***Investment potential in local software engineers****:* Boardrooms of Papua New Guinean companies were characterised as "non-techy" by the participants of our focus group:

> *"If you see our executives, they are all fifty-plus, they are all old-school, they don't understand that tech plays an essential role in this day and age. [...] Our IT guys are lower down in the hierarchy, so they're not sitting with management." –P2*

As a consequence, companies do not invest in training through software engineering internships or joint courses with industry. While such internships exist in the mining sector, and mechanical and system engineering have internships and graduate programs, there are no internships in IT or software engineering:

> *"So when it comes to software, because the people at the top don't understand, we don't design the software according to what the requirements are, so it usually comes out not the way we expect it to." –P1*

e) ***Establish trust in local software engineers****:* Taken together, the limited dedicated software engineering training and investment in the local software engineering workforce lead to

trust issues in the abilities of the local workforce—a classic "chicken-and-egg" problem: Trust will only increase once the workforce is well-educated. Still, at the moment, investment goes to foreign entities rather than the local workforce, as P4 highlights:

> *"If we tender for a project, like let's say the government, they're likely to get another firm outside, not a Papua New Guinean firm." –P4*

Developing trust in the local software engineering workforce is as much a cultural issue as it is an educational issue:

> *"The problem we have not only in PNG but in the Pacific Islands is we don't trust our own [...] we need to pay for someone to be an international person to join us so that they can trust us. [...] Because we don't trust our own qualification. It comes down to that. [...] The mentality is the answers are always outside rather than inside, so they would pay larger amounts of money for someone outside rather than trusting someone inside." –P1*

B. Member checking

We sent a follow-up survey to 28 participants (i.e., the focus group participants, invited speakers, and survey participants who left their contact details) to further assess the credibility of our themes. Seven participants responded to the survey (response rate of 25%). Participants strongly confirm statements relating to three of our five themes, but interestingly, there was no consistent agreement about the use of global technology, such as open source and global platforms like GitHub and Stack Overflow (early stages of technological leapfrogging) and whether dedicated SE training was up-to-date (training).

V. Inclusive Best Practices

We synthesized insights from our work into best practices for local practitioners, researchers, and educators.

Market focused on customising off-the-shelf Early stages of technological leapfrogging Limited dedicated SE training Investment potential in local SE Establish trust in local SE

a) For Local Practitioners: We identify three practices that local SE practitioners could do to help the situation. This would be in the form of offering more (i) training, (ii) internships and (iii) lowering the barrier for startup companies. Conducting short-term training to help onboarding local developers to create a local workforce capable of fulfilling the technical needs is an important step. It would directly address the themes of 'limited dedicated SE training' and indirectly enable the market to not solely focus on customising off-the-shelf software if custom solutions can be built in PNG. Moreover, a qualified local workforce will help 'establish trust in local SE' and lowering the barriers for startup companies will help with the 'investment potential in local SE'. Our findings indicate that supporting local actors in an emerging society to become members of the global software development community can contribute to the sustainability of software engineering. Such engagement could, for example, happen in the context of open-source software, through contribution and knowledge-sharing with global platforms such as GitHub and Stack Overflow.

b) For Researchers: Similarly to Craggs and Rashid [13], we also identified trust as a crucial concept in our study. Further research is needed on how to establish trust in the local workforce in an emerging society, taking the important role of training investment into account. More work is needed to understand what the predictors are for the success of such programs in a given society, similar to a recent case study in Ireland [14]. Inclusion in the global SE should be encouraged, for example, participation to international conferences leading to exposure to cutting edge technology. Researchers should explore how global communication channels and social media can be leveraged as practices to help include the local SE communities from emerging societies.

c) For Educators: Our findings indicate a need to update the existing education curricula related to software engineering. The focus should be on upgrading the capacity of local educators as well as importing foreign education. This should be a higher priority than simply offshoring work, which can become costly in the long run. Global initiatives such as Google Summer of Code (GSoC) are partly aimed at emerging societies, and have found large uptake in some of them.

VI. Conclusion

The emerging society of PNG has only recently reached the digital age frontiers, with early signs of a local SE community. We contribute a characterisation of the current state of SE in education and industry, along with the identification of challenges and possible practices to enable emerging societies like PNG to participate in the global SE community. While we cannot claim generalisation of our results beyond PNG, we expect that our insights and best practices can be transferred to similar emerging societies. Our future work will focus on confirming this assumption.

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