Preliminary analysis of a survey of Research Software Engineers in the UK

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Olivier Philippe
Software Sustainability Institute
University of Southampton
Southampton, SO17 1BJ
Email: o.philippe@software.ac.uk

Neil Chue Hong
Software Sustainability Institute
University of Edinburgh
Edinburgh, EH9 3JU
Email: n.chuehong@software.ac.uk

Simon Hettrick
Software Sustainability Institute
University of Southampton
Southampton, SO17 1BJ
Email: s.hettrick@software.ac.uk

***Abstract*—This paper presents results from a survey conducted on a new role in academia: the Research Software Engineer (*RSE*). The survey provides much needed demographic information about the education, field, gender, job satisfaction and career plans of the people of *RSEs*. The community is found to be highly educated, derive mainly from the hard sciences, and to be predominantly male. Respondents report satisfaction in their jobs, but indicate that career progression is both difficult and opaque.**

This paper supports a continued discussion about the experience of *RSEs* and recommends further investigation into this important community.

I. Introduction

The term *Research Software Engineer (RSE)* was coined in 2012 in a paper [1] that described the situation of people in academia who write software used by researchers. At the time, little was known about software use in research, but even less was known about the people who develop, maintain and extend that code. The term was chosen because it fuses the two skills that are necessary to the role: an understanding of research, and an understanding of software engineering.

It is noted that the term *RSEs* is intended to be interpreted broadly, it does not imply that the only people who can inhabit the role derive from a software engineering background. Indeed, most *RSEs* come from a background other than software engineering.

In a 2014 survey [2], the Software Sustainability Institute found that almost 70% of researchers from across domains relied on software for the generation of their results, which shows the fundamental importance of software to research. The availability of this software and its reliability are completely dependent on the skills of the person or people who develop it. Although some academics will choose to adopt the skills they need to engineer reliable software, many will not have either the time or inclination to do so. A more scalable and sustainable approach to embedding these skills in academia is to ensure that academics have access to *RSEs*.

The Software Sustainability Institute began a campaign in 2013 to increase the availability of *RSEs* by ensuring they had a viable career path in academia. To provide a more accurate picture of the communitys development, it was decided to start an annual survey to collect demographics. This paper shares the results of this survey and uses these results to infer conclusions about the community.

II. Sample and Methodology

The RSE role is performed by people from a wide range of backgrounds. Anecdotally it appeared that most *RSEs* came from a research background, albeit one that had allowed them to amass software engineering skills. It appeared that a minority came from a background of formal training in software engineering. This wide range of backgrounds, expertise and education means that it is not currently possible to provide a concise summary of the RSE role which does not overlook some part of the RSE community. Until such a definition exists, it was decided to take an inclusive approach to defining the RSE role by allowing *RSEs* to self-identify.

To target *RSEs* directly, the survey was sent via email to the UKRSE Associations mailing list. Two further reminders were sent to the list to elicit responses from the community. People who received these emails helped to disseminate the survey via email, on blogs and using Twitter and other social media.

In total, 592 responses were received, but only 367 of these were complete (*i.e. where all mandatory questions had been answered*). The survey was devised to investigate *RSEs* in the UK, but dissemination of the survey had resulted in responses from around the world. This first analysis was focuses on UK, and hence on the 335 complete responses from UK-based participants.

III. Gender, level of education and academic background

The first set of questions investigated the university at which people work, their field and level of education, and their gender.

The most striking result from this survey is that there are far fewer female *RSEs* than male. Only 11% of the participants were female, and it is assumed that this is representative of the UK community of *RSEs*. This is a low level of female participation even by the poor standards of UK computer science (14%), which has one of the worst gender disparities in academia.

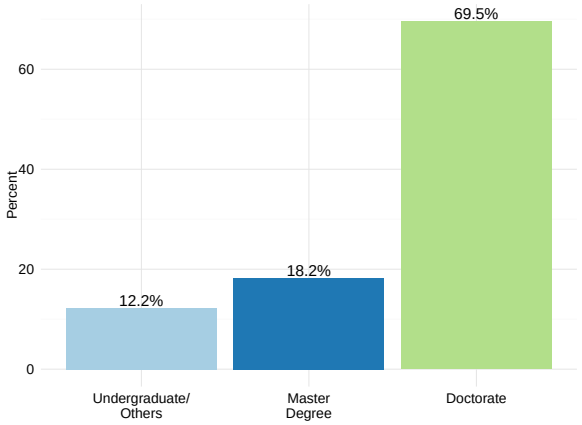

Fig. 1. Level of education

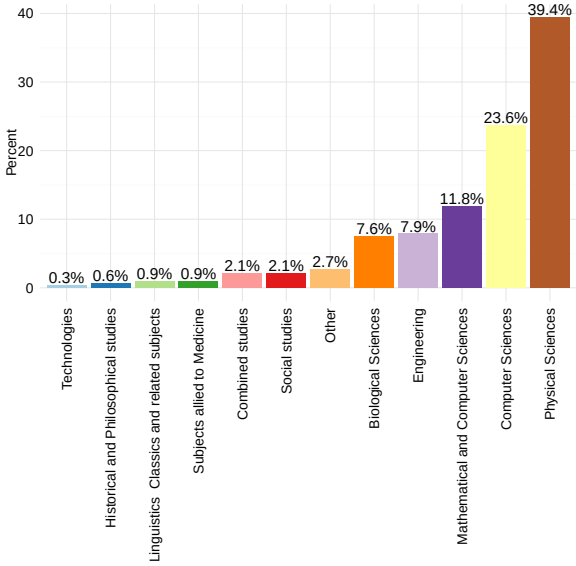

Fig. 2. Academic field

It is argued that *RSEs* are more effective at academic software development than a consultant software engineer, because they understand not just software engineering but research too. With 69.5% of participants reporting a doctorate as their highest degree (see Fig. 1), and a further 18.2% reporting a masters degree, it would appear that this argument is sound. The majority of *RSEs* have worked as a researcher, which will provide them with an intimate knowledge of the research process, its incentives and idiosyncrasies.

The educational background of the participants was determined by asking about the field of their highest degree (see Fig. 1). The Joint Academic Coding System (JACS) [3] was used to classify the field. JACS provides a system for grouping together academic subjects, which at the top-level distills the many hundreds of academic subjects into 22 different JACS codes. It is occasionally contentious, for example, in grouping together veterinary science and agriculture, but there is no more widely accepted system of academic classification in UK academia.

The largest proportion of *RSEs* gained their highest degree in the physical sciences (39.4%, n=130) followed by computer sciences (23.6%, n=78). These subjects alone accounted for 63% of all participants. It is noted that physical sciences and not computer sciences, as was commonly accepted, are the origin of the most participants in the survey, and it would seem reasonable to predict that this reflects the UK RSE community. The next 27% of respondents derive from mathematical sciences and computer sciences (11.8%), engineering (7.9%) and biological sciences (7.6%). After this point, no single JACS code accounts for more than 3% of the participants.

Aside from the unexpected leading position of physicists, the educational background of *RSEs* follows the expected trend, with the ”hard sciences” providing significantly more participants than other educational domains.

IV. Good practices and paper participation

RSEs combine an understanding of software engineering and research practices, so we might expect them to report aspects of both roles in their work, for example best development practices (development side) and paper publications (research side).

Although the survey was primarily aimed at understanding the RSE community, it also presented an opportunity to investigate the sustainability of the research software projects on which the *RSEs* worked. We chose two broad measures to provide an insight into sustainability: the bus factor and technical hand over planning.

The bus factor is a measure of the number of developers who understand a specific software project and could, with only a cursory review of the project, maintain or extend the code. A project with a bus factor of 1 is completely reliant on only one developer. If this developer finds new employment, becomes ill or is hit by the titular bus, then the project will fail. A high bus factor provides some confidence that the project can be sustained even if a developer leaves.

A technical hand over plan is used to introduce a new developer to a software project. These plans cover basic information, such as the licence and location of the software repository, a description of the software architecture, a summary of development plans and any other information that a new developer would need to understand the software. A project that has written (and maintained) a technical hand over plan can withstand the departure of a developer, even a key developer, significantly better than one without such a plan.

A cause of much controversy in academia is the subject of who should be named on a paper. Researchers are well aware of the importance of papers and citations to their reputation and the progression of their career, and as a consequence they will fiercely argue for inclusion on papers covering work to which they have contributed. One of the complaints heard from the RSE community is that *RSEs* are not recognised for their, sometimes significant, contribution to research. To

TABLE I
BUS FACTORS

Bus factor	Total Respondents	Percent
1	143	44.69
2	99	30.64
3	36	11.25
4	15	4.69
5	27	8.44

investigate the recognition of RSEs in academia the survey focussed on whether they had contributed to research that was published in a paper, and whether they were acknowledged for that contribution.

A. Good practices

The results reported for bus factor (see table I) show that the majority of RSEs (46%, n=117) are part of a development team consisting of only one person. It is tempting to seize on this figure and lambast research groups for under-investing in software developers in their team and, in doing so, putting at risk the reliability of their software. We must keep in mind the significant financial restrictions placed on research groups, and that it is unlikely that many researchers would refuse to employ more RSEs if they were given the resources to do so. However, we can conclude that almost half of the research projects included in this survey rely on only one developer, and this is a significant risk to the sustainability of these projects.

A bus factor of two (or greater) is reasonable for a research group, and just over half of the projects surveyed reported this level of support.

Only 24% of RSEs reported that their software project has a technical hand over plan. Whereas research projects can be forgiven for being over-reliant on too few developers due to the lack of resources, there is little excuse for not developing a technical hand over plan. Almost three quarters of the projects included in this survey report having no technical hand over plan, which puts them at significant risk of sabotaging their own sustainability. The importance of technical hand over plans must be raised with the research community in an attempt to convince more projects to write one.

B. Contribution to publications

Although 88.2% (n=284) of RSEs reported contributing to research that was later published in a paper, 30% of these RSEs were not listed as an author.

RSEs more typically receive an acknowledgment in the paper for their contribution (76%, n=278) rather than being named on the paper. It is unusual for an RSE to be named as the lead author on a paper (40% n=147), which could indicate that they are unlikely to conduct their own research. It will be illuminating to conduct follow-up analysis of these RSEs to see where they are publishing their papers and whether the paper focuses on research made possible by software, or on the software itself. More RSEs have been named as a co-author (69% n=253) than as a lead author.

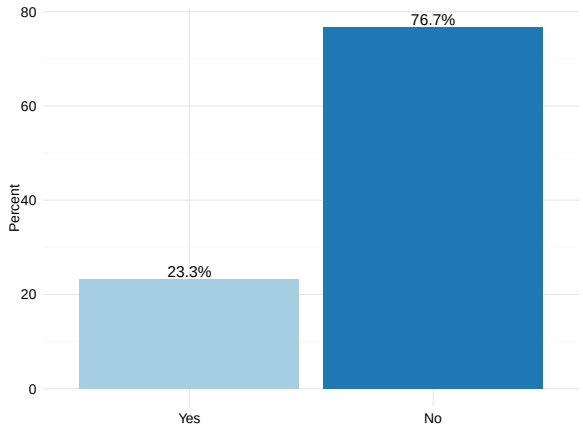

Fig. 3. Technical handover

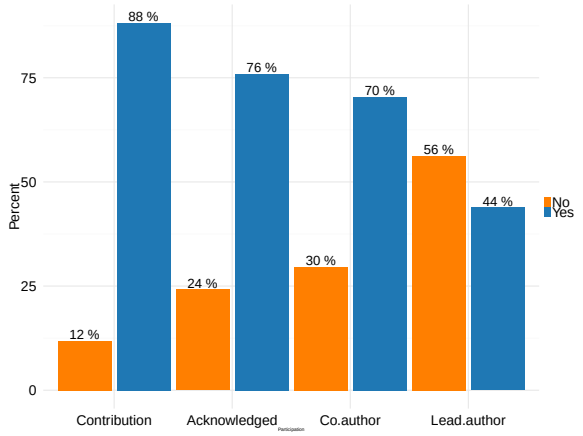

Fig. 4. Contribution to papers

V. WORK INDICATORS

How to measure the quality of a job has been debated in psychology for a long time [4]. Several models exist to understand the link between different factors of job satisfaction and turnover intention [5]–[9]. Turnover intention is an important measure that is highly associated with the risk of employees leaving the organisation [7]. Job satisfaction is important in retaining *RSEs*. Perceived employability provides information on how workers values their own skills in regard of the market.

To measure the different attitudes toward the RSE role, we used scales that have been created in [5], [6], [8], [9]. These are *Likert scale* [10], which are 5 point ordinal scales graduated from *Strongly disagree* to *Strongly agree*. Each scale is composed of several so called *items* (i.e. questions) that each measure one attitude.

There is significant debate about the use of a Likert scale [11]. According to a review by Normam [12], parametric tests are a valid and robust options for ordinal data, as long as there are sufficient responses per category (at least 5). The second argument is about aggregating several items from a scale into a single measure. This approach is often used when a scale is used to measure a broader concept by aggregating items to

TABLE II
CRONBACH ALPHA FOR THE WORK INDICATORS

Scale	Cronbach Alpha	Number of items (*questions*)
Turnover intention	0.817	6
Feedback	0.931	5
Perceived employability	0.838	4
Job satisfaction	0.92	4
Performance checking	0.891	7

TABLE III
TURNOVER INTENTION QUESTIONS

How often do you feel frustrated when not given the opportunity to achieve your personal work related goals?
How often do you look forward to another day at work?
My current job satisfies my personal needs
I would accept another job at the same compensation level if I was offered it
How often do you consider leaving your job?
How often do dream about getting another job that will better suit your needs?

produce a total or mean score [13].

It is important to check that a scale is measuring only a single concept and to check if all items are effectively measuring the underlying attitude. The most common used test for internal consistency is the *Cronbach Alpha* [14]. This test's measure is expressed as a number between 0 and 1, where a good reliability is indicated by an score of 0.7 to 0.95 [15]. A value under this range indicates a poor reliablility, while a value over the range indicates an overlap of items [16].

The scales used in this study were developed and tested in previous research [4], [5], [7], [8].

We calculated the *Cronbach Alpha* for each scale we measured and, as shown in table II, found a good internal consistency meaning that it is safe to aggregate the items of each scale into one measure. The aggregation was performed by attributing a score from 1 to 5 for each category and calculating the mean of this aggregate score for the sample (see Fig. 5).

Turnover intention has a low aggregate score (m=0.681, sd=0.825), which indicates that *RSEs* in the main do not intend to quit their current position. Taken alone, this measure could be understood if *RSEs* are happy in their current position, if they believe their skills are not needed, or if the market is oversaturated. However, other measures discussed below remove some of these possibilities.

RSEs believe that their skills are much in demand: reporting a perceived employability score of m=3.566 (sd=0.922) out of a potential maximum score of 5.0. They also indicate being satisfied that their work is appreciated (item Satisfaction), with a relative high score (m=3.653, sd=0.959), and on the recognition they gain from their colleagues and co-workers

TABLE IV
PERCEIVED EMPLOYABILITY QUESTIONS

It would not be very difficult for me to get an equivalent job in a different organisation
I can think of a number of organisations that would probably offer me a job
My experience is in demand on the labour market

TABLE V
FEEDBACK QUESTIONS

I am satisfied with the recognition I receive from my supervisor/line manager for doing my job
I am satisfied with the compliments from my supervisor/line manager concerning my work
I am satisfied with the encouragement from my supervisor/line manager while doing my job

TABLE VI
PERFORMANCE CHECKING QUESTIONS

Do you receive sufficient information on the results of your work?
Does your work give you the opportunity to check on how well you are doing your work?
In your work, do you have access to sufficient data and information?
Do you receive sufficient information on the purpose of your work?
Does your work provide you with direct feedback on how well you are doing your work?
Does your supervisor/line manager inform you about how well you are doing your work?
Do your colleagues inform you about how well you are doing your work?

TABLE VII
SATISFACTION QUESTIONS

I find real enjoyment in my job
Most days I am enthusiastic about my job
I feel fairly well satisfied with my job

(m=3.537, sd=0.988). On the feedback they received from their hierarchy or colleagues (item Feedback), the score is slightly lower (m=3.022, sd=0.831)

It would appear that *RSEs* are happy in their positions, because they report a low turnover intention, even though their skills are in demand, and satisfaction in the way they are perceived. This runs contrary to the commonly heard complaints of the RSE community, so further analysis must be conducted to understand these results. A series of interviews with *RSEs* is planned to investigate this issue in more depth.

VI. CAREER PATH AND OPPORTUNITIES

An attractive career path *RSEs* must offer an obvious route to promotion within the group. We asked 5 questions to investigate how RSEs viewed their career plan (see the table VIII and fig. 6).

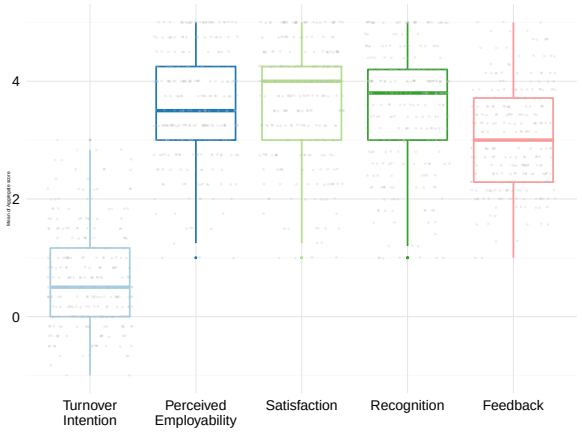

Fig. 5. Job satisfaction factors

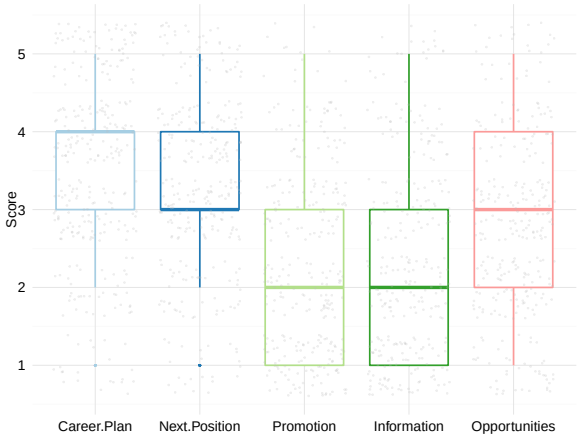

Fig. 6. Career path

TABLE VIII
PROGRESSION QUESTIONS

My current position is an integral part of my career plan
It is likely that my next position will be an RSE role
It is likely that I will gain a promotion within my current group
The process I have to complete to gain a promotion is clear and understandable
There are many opportunities within my chosen career plan

TABLE IX
RESULTS FOR SPECIFIC RSE QUESTIONS

Questions	Nbr of Yes
Do you spend more time developing software than conducting research?	241
Are you employed primarily to develop software for research?	193
Are you the person who does computers in your research group?	136
Are you employed as a postdoctoral researcher?	95

Participants appear to see their current position as a desired step in their career plan (item *Career.Plan*) with a high score in general (m=3.453, sd=1.183) and they also report that their next position is likely to also be an RSE role (item *Next.Position*), (m=3.285, sd=1.135). This indicates that *RSEs* are choosing their role and the result for *Next.Position* could be argued to show that *RSEs* are choosing, not just a job, but a career in Research Software Engineering. However, they are less positive about the opportunities for promotion (item *Promotion*) (m=2.315, sd=1.202). They also report a lack of information on the promotion process (item *Information*) (m=2.353, sd=1.247), which is understandable because the RSE role is not yet a sanctioned career in academia and hence does not attract institutional support. *RSEs* are more neutral about opportunities (item *opportunities*) (m=2.758, sd=1.162).

VII. IDENTIFYING RSES

The problems of identifying *RSEs*, and hence the reason why they are asked to self-identify, is discussed above. The UKRSE Association[1] were the first to encounter this problem and as a consequence had developed a number of questions to help potential *RSEs* align themselves with the role. These questions are as follows:

1) *Are you employed primarily to develop software for research?*
2) *Do you spend more time developing software than conducting research?*
3) *Are you employed as a postdoctoral researcher?*
4) *Are you the person who does computers in your research group?*

The above questions were devised to appeal to people who worked in a research environment but wrote software rather than papers, and were based on the experiences of a group of people who had worked in the RSE role. They were designed to identify aspects that, anecdotally at least, appeared to unite *RSEs* from all backgrounds. For example, many appeared to have been recruited into postdoctoral positions, and many were referred to as the person ”who does computers” by their less technologically adept colleagues. The above questions are broad, and even colloquial at times, to appeal to the intended audience and present the RSE community as inclusive. *RSEs* were said to have self-identified once they had joined the UKRSE Association.

To investigate the effectiveness of the above questions in identifying *RSEs*, they were included in the RSE survey. The results (see table IX) indicate that, unsurprisingly, the most effective way of identifying *RSEs* is to focus on software development: 72% (n=241) reported that they spend more time developing software than conducting research, and 58% (n=193) reported that they are employed primarily to develop software for research. The question about the person who does computers was agreed with by 40% (n=136) of participants,

[1]http://www.rse.ac.uk/

which indicates that this colloquial approach appeals to a substantial number of *RSEs*. Only 28% (n=95) of participants reported that they are employed in a postdoctoral position. It would appear that the widely held belief that most *RSEs* are employed as postdoctoral researchers is untrue.

Although four questions were devised to identify *RSEs*, it would appear that there is significant agreement only with the questions related to time spent performing software development. This result will be communicated with the UKRSE Association so that they can decide on whether to change their approach to recruitment *RSEs*.

VIII. Conclusion

Any new community venture has to begin life without the support of hard evidence. It must first be shown to have gained traction with its target community before that community will have sufficient incentive to contribute to evidence gathering. This was the situation with the RSE community in early 2016: it had gained significant interest, membership had grown to a significant size, but the tenets on which the community was based were supported mainly by anecdotal evidence. The *RSE* survey described in this paper provides evidence for the first time about this important community.

It would appear that many assumptions about the community are correct. They are have an intimate knowledge of research, with 69.5% holding a doctorate, and they mainly derive from a background in the physical science and computer sciences. Anyone who spends time with this community will realise that it is predominantly male, as shown by the small number of female participants to the survey: a mere 11%. This gender imbalance is an issue of much debate across STEM subjects, which provides a potential area of collaboration for the RSE community and route to addressing the issue. It is noted that the RSE community has accepted this issue and is already working to improve representation across its membership.

The survey investigated two measures of the sustainability of the software on which *RSEs* work. It was found that 46% of *RSEs* work on projects with a bus factor of 1 and, potentially more worrying, 6% of *RSEs* work on projects where no technical hand over plan exists. The concepts of software sustainability are still relatively new to many in the research community, and it would appear that there is much work to be done to ensure that the community can sustain its own work - at least according to these broad measures.

It has long been argued that *RSEs* are not acknowledged in papers. This argument is supported by the survey which found that despite 88.2% of *RSEs* contributing to a result that appeared in publication, 24% of these *RSEs* were not even acknowledged in the paper. Paper publications might not be the most appropriate mechanism for acknowledging the work of *RSEs*, but whilst other metrics are determined, we must work to ensure that they are acknowledged for their contribution by conventional measures.

We investigated attitudes towards the RSE career using robust and previously assessed scales. *Turnover intention* is a critical aspect, because it informs us of fragility of the community. The participants did not express any significant desire to leave their current position, which indicates that the community is robust The affective side (*job satisfaction*), the cognitive aspect (*perceived employability*), and the social aspect (*recognition*) of the *RSE* role were investigated are were positive.

The *RSE* career plan is not viewed as positively. Although *RSEs* appear to have chosen their position and indicate a desire to stay in the role, they are less positive about the likelihood of promotion and access to information about it. This could be a warning sign of a dead-end career path.

This positive attitude despite a weak career plan could be explained by the novelty of their role and the interest this generates. Longitudinal analysis is needed to develop a deeper understanding of this result, but the conclusion based on this survey is that *RSEs* feel positive about their role.

Plans are now in place to conduct this study in countries other than the UK. It would be enlightening to conduct the same analysis of software engineers working in industrial research (e.g. in R&D departments) to a relative measure against which research software engineering can be related.

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