Impact case study (REF3)

Institution: Cardiff University

Unit of Assessment: Mathematical Sciences (10)

Title of case study: Growing open and sustainable software communities across Africa

Period when the underpinning research was undertaken: 2013 – 2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Vincent Knight	Senior Lecturer	01/04/2009 – present
Geraint Palmer	Lecturer	18/09/2017 – present
Paul Harper	Professor	01/09/2007 – present

Period when the claimed impact occurred: 02/02/2015 – 30/06/2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact (indicative maximum 100 words)

Open and sustainable coding is a vital enabling technology, particularly in regions where commercial software licenses and pricing are restrictive. Cardiff's use of open and sustainable coding within operational research and game theory led to the team playing a key role in the first Python conference in Namibia in 2015. Cardiff's demonstration of their research at the conference was integral to the formation of a new self-sustaining Namibian Python community, as well as an annual user conference. These Namibian events inspired new user communities in Nigeria and Zimbabwe, which led to the first Python Africa conference in 2019, attracting hundreds of delegates from around the world. The community's growth across Africa additionally led to improved job prospects for attendees, new educational opportunities for schoolchildren, and acclaim and support from the Python Software Foundation.

2. Underpinning research (indicative maximum 500 words)

Mathematical research is not always reproducible due to unreliable, obscured, or outdated computer code. Open and sustainable software is a powerful approach to ensuring accessible software across the world, especially in areas where ongoing and prohibitively priced licenses can restrict the use of bespoke software. **Sustainable software** is broadly defined as reliable code with reproducible results, often enabled by **open software**, wherein source code is made publicly available for all to view.

The Cardiff School of Mathematics' open and sustainable software approaches are core to the delivery of its research. This is further evidenced by the open research approach of Cardiff mathematicians (Knight, Palmer and Harper), as well as Knight and Palmer's positions as fellows with the Engineering and Physical Science's Research Council (EPSRC)'s Software Sustainability Institute.

2.1. Modelling of queueing networks

The early work of the Cardiff team in queueing theory explored strategic behaviour in queueing systems under variable levels of information **[3.1]** and was presented at the inaugural 2015 Namibian Python conference. Cardiff's research into queueing systems established a sustainable framework for understanding potential deadlock in queueing networks. This framework describes a mathematical approach that uses queueing theory as well as graph theory to be able to identify when a queueing network might arrive at deadlock **[3.2]**. The approach ensures modelling of queueing networks can be made more realistic: in a model, a deadlock situation would essentially block all analysis, where in reality it might be recognised and dealt with.

This work was incorporated by the Cardiff team into the open-source simulation package 'Ciw' **[3.3]** which provides an alternative to commercial analytical software, and due to its openness, allows simulation models to be tested, reproduced, and modified by users to suit their own needs. Ciw has been used in a variety of research and education projects, including supporting

improvements to cancer healthcare for NHS Wales (as outlined in a further Cardiff UoA 10 impact case study).

2.2. Open-source game theory strategies

The second relevant area of research is in applications of game theory, developed from early work on the effect of selfish behaviour on the efficiency of queueing systems **[3.4]**. Knight further developed software that explored the evolution of cooperative behaviour by providing a framework for research in the Prisoner's Dilemma **[3.5]**. This software is named 'Axelrod' and contains a collection of more than 200 strategies tested, documented and available to researchers throughout the world.

The open-source design of the Axelrod library is integral to the research. By opening up the source code, the user base can contribute strategies, creating a larger and more robust repository than if the software was closed and allowing Axelrod to be maintained by the user community. Cardiff researchers have since used Axelrod to collaborate on further game theory analyses, utilising its open and sustainable nature to enable a collaborative approach. An example is **[3.6]**, where the researchers used novel machine learning techniques to understand fundamental emergent behaviours. This was made possible due to the diverse training environment that Axelrod provides from its large training pool of open source strategies.

Cardiff research, and demonstrations of both Ciw and Axelrod were provided at the first Python Conference in Namibia 2015. The research on queueing networks **[3.1]** highlighted an accessible method of addressing problems encountered in healthcare and commerce. The presentation of game theory strategies **[3.4]** inspired the formation of the Axelrod library of strategies **[3.5]**. Both research strands focused on making applied research accessible through being open-source and freely available to be studied and used by others.

3. References to the research (indicative maximum of six references)

[3.1] 2013: Comparisons between observable and unobservable M/M/1 queues with respect to optimal customer behavior: R Shone, **V Knight**, J Williams - *European Journal of Operational Research* https://doi.org/10.1016/j.ejor.2012.12.016

[3.2] 2017: Modelling deadlock in open restricted queueing networks: **G Palmer**, **P Harper**, **V Knight**. *European Journal of Operational Research* https://doi.org/10.1016/j.ejor.2017.10.039

[3.3] 2017: Ciw: An open source discrete event simulation library: **G Palmer**, **V Knight**, **P Harper**, A Hawa. *Journal of Simulation* https://doi.org/10.1080/17477778.2018.1473909

[3.4] 2013: Selfish routing in public services: **V Knight** and **P Harper**, *European Journal of Operational Research 230* (1), pp. 122-132 https://doi.org/10.1016/j.ejor.2013.04.003

[3.5] 2016: An Open Framework for the Reproducible Study of the Iterated Prisoner's Dilemma: **V Knight**, O Campbell, M Harper, K Langner, J Campbell, T Campbell, A Carney, M Chorley, C Davidson-Pilon, K Glass, N Glynatsi, T Ehrlich, M Jones, G Koutsovoulos, H Tibble, J Müller, **G Palmer**, P Petunov, P Slavin, T Standen, L Visintini, K Molden. *Journal of open research software*. https://openresearchsoftware.metajnl.com/articles/10.5334/jors.125/

[3.6] 2017: Evolution Reinforces Cooperation with the Emergence of Self-Recognition Mechanisms: an empirical study of the Moran process for the Iterated Prisoner's dilemma**: V Knight**, M Harper, N Glynatsi, O Campbell. *PLOS One* 1 https://doi.org/10.1371/journal.pone.0204981

4. Details of the impact

Demonstration of Cardiff's research inspired a new and self-sustaining international community of Python users across Africa. Through Cardiff's expertise in deploying open-source research and tools to resolve practical problems, the Cardiff team facilitated widespread adoption of open-source analytical techniques across Africa, fostering new employment and educational opportunities. Growth in the African Python community is demonstrated by:

1. launch of the first Python Conference in Namibia;

2. formation of the Namibian Python Society, which attracted new users and led to vital training opportunities and growth in skills across the country;

3. creation of new Python-user communities in Zimbabwe and Nigeria;

4. the first pan-African Python-user conference, facilitated by increased financial investment across Africa from the international Python Software Foundation.

4.1 Launching the first Python Conference in Namibia

In 2014 Cardiff University and the University of Namibia launched the Phoenix Project, focused on using education to improve living conditions, reduce poverty, and promote sustainable development. Danielle Procida, a lead organiser in the Phoenix Project at Cardiff, sought to establish Namibia's first Python Conference (PyCon) with the aim of growing and encouraging use of Python across the country. "*Inspired by Dr Knight's work*", Procida recruited him as "*an ideal collaborator in the first and subsequent Namibian PyCons*", due to his "*expertise in leading research in, and communicating the purpose of, sustainable, open-source software*" **[5.1]**. Knight and Palmer were therefore invited to present their research and support the first PyCon at the University of Namibia between 2 and 5 February 2015.

At PyCon 2015, Knight demonstrated the resolution of real-world applications of mathematics problems drawing upon Ciw and its uses in healthcare settings **[3.1, 3.2]**. After presenting research on game theory strategies **[3.4]**, and building on interest from participants, the foundations of the Axelrod library **[3.5]** was created at the PyCon as a working model of the sustainability and robustness of open-source tools. The library has since been used to practise the design of strategies for the Prisoner's Dilemma by teenagers learning Python in Namibia, and adapted to produce a working model of rhino-poaching as game theory, presented at later PyCons **[5.1]**.

4.2 The formation of PyNam: The Namibian Python Society

The first Namibian Python society, PyNam, was formed during the last day of PyCon, with attendee Jessica Upani elected as president. The Cardiff team gave the first demonstration of Python at PyCon Namibia 2015, and Upani noted how their research demonstrated the potential to use mathematical analysis to solve wider problems through Python **[5.2]**. She stated that "*the research presented during the sessions inspired us to form PyNam, a team of Namibian coders and academics passionate about creating a platform for sustainable programming and analysis in Namibia*" **[5.2]**.

The PyNam team has since hosted annual PyCons in Namibia, and the 2020 PyNam conference attracted over 100 attendees from 15 countries across Africa, Europe, and North America **[5.3]**. A key strength of Namibian PyCons is their diversity: by 2019 50% of attendees were women, and one in three talks were delivered by female presenters **[5.4]**. Upani notes that the Python community in Namibia extends beyond the PyCons, and most users stem from community groups such as school coding clubs, small user groups, and 'Django Girls': a coding club for women of all ages and backgrounds **[5.2]**. The growth of Python users is acknowledged by the Python Software Foundation, the global body that disseminates official updates to Python. Marlene Mhangami is the first African Board Director of the Python Software Foundation, and after personally attending the 2018 PyCon Namibia noted that she "*cannot overstate its impact on the African developer community*" **[5.5]**. Mhangami praised the fact that subsequent Namibian PyCons were organised entirely by the local Namibian Python society: "*This speaks to the great work by the Cardiff team to make these efforts sustainable and empowering to Namibians*" **[5.5]**.

Namibian Python events have delivered broad impact in adoption and application of skills across Africa. For example, Procida highlighted how, following their attendance at the event, statisticians from the Namibian Statistics Agency have developed analytical tools within Python, and enabled factories in Zimbabwe to solve logistical challenges through Python-based solutions **[5.1]**. The PyNam team established further community user groups, including a coding group for Namibian high-school students called the PyNam Scholars **[5.2]**. The PyNam Scholars organise their own two-day programming workshops and achieved national recognition by winning the 2017 Namibian programming competition. In 2020 alone, nine former PyNam Scholars started new careers in software development and cyber security fields after graduating from school **[5.2]**. The

PyNam team highlighted how Python communities have developed local software capacity and skills and are: "*directly responsible for advances in the careers of Namibian programmers, and for initiatives within Namibia to build on local talent and energy*" **[5.3]**.

4.3 Continuing growth across the Continent

The success of the PyNam team has inspired the growth of user communities across Africa. Aisha Bello (from Nigeria) attended PyCon Namibia 2016, which "*helped shaped the career choices and ambition that still drives me till this day"* and gave her "*the right motivation and inspiration that I took back to my home country to help found the Python Nigeria Community*" **[5.6a]**. The Nigerian Python Community established by Bello has grown to include more than 1.5K members and held more than 35 Python events in 2017 **[5.6b]**. The 2018 PyCon Nigeria attracted over 250 attendees: while modest figures for PyCons in developed countries, Procida notes that "*typically delegates are representing much wider groups from their own regions*" due to the expense of travel within the continent **[5.1]**. Bello highlights the Nigerian Python community has fostered a supportive role that provides "*a platform for newbies to get into technology"* **[5.6]**.

The 2016 PyCon Namibia event also inspired software engineer Anna Makarudze from Zimbabwe to co-organise the first two PyCon Zimbabwe events in 2016 and 2017, as well as several Django Girls events. Makarudze has been able to secure a career and stated: "*PyCon Namibia has been life changing for me as it enabled me to make my dream of telecommuting as a software engineer come true*" **[5.7]**. Makarudze has since become the President of the Django Software Foundation: a non-profit organisation committed to Python-based, open-source web applications and training programmes around the world.

The Python Software Foundation cited the collaboration between Cardiff and the University of Namibia as fundamental to the rise of Python user communities across Africa. Mhangami highlighted the influence of PyCon Namibia 2015 upon attendees "*who, following the conference went on to organize PyCons in their home countries. As a result of this we have seen tremendous growth in the use of Python in the Southern and Western parts of Africa*" **[5.5]**.

4.4 The first PyCon Africa in 2019

The rise in Python communities across Africa led to the first pan-African PyCon, which took place in August 2019 in Accra, Ghana. The five day "PyAfrica" conference was attended by 323 people from 26 countries across Africa, Europe, North and South America. The conference included keynote talks from the head of Google's AI Center in Accra on statistical modelling of disease spread and flood forecasting, a presentation by the executive director of the Python Software foundation, and various workshops with introductions to data science, analytics, and statistical analysis. On the PyAfrica website listing their key supporters, the Cardiff-Namibia Phoenix Project is highlighted first: "*The Phoenix Project helped start and sustain Namibia's Python community and its PyCon, which in turn led directly to PyCons in Zimbabwe and Nigeria*" **[5.8]**.

The Python Software Foundation have increased their funding to African Python groups to reflect the growth in the community. In 2008, the Python Software Foundation gave one grant to Africa (PyCon South Africa) **[5.9**, p.7**]**: between 2012 and 2014 investment remained small, specifically between $500 - $2K per annum for events in Africa **[5.10]**. In 2019, The Python Software Foundation's 2019 Annual Report states: "Now, 25% of our funds go to Africa thanks to the work of several communities such as Python Nigeria, Python Ghana, Zimbabwe and Namibia" **[5.9**, p.7**]**. This amounts to approximately $83.5K invested in African Python User Groups and PyCons in 2018 **[5.10]**.

Since the Namibian Python Society in 2015, wider community groups have fostered new skills and opportunities. PyNam President Upani notes how Cardiff's research "*inspired a generation of coders and analysts in Namibia, who have in turn inspired, taught and worked with the wider African community to make Python a force for good across the continent*" **[5.2]**. The organic growth in user communities has led to varied impacts, demonstrated by Procida's observations of how Python has since been widely applied to support employment, including ensuring market traders are maximising sales, create model queueing networks (often inspired by or utilising code directly from Ciw), streamlining waste management, assisting maximum productivity for soap

manufacturers, tracking shipments travelling across the continent and a host of other every day, practical uses, using bespoke, user-built and user-owned software **[5.11]**.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[5.1] Letter of support from Daniele Procida, lead organiser of PyCon Namibia 2015

[5.2] Letter of support from PyNam President, Jessica Upani, confirming the role of Cardiff's research in inspiring the launch of the first PyCon Namibia in 2015

[5.3] PyCon Namibia 2020 homepage

[5.4] PyCon Namibia Webpage: "Looking back at PyCon Namibia 2019"

[5.5] Letter of support from Marlene Mhangami, Director of the Python Software Foundation, endorsing the role of Cardiff University in fostering the growth of Python across Africa

[5.6] a. Quotation from Aisha Bello on inspiration from PyCon Namibia 2016 to start PyCon Nigeria **b.** Presentation by Marlene Mhangami on Python growth in Nigeria

[5.7] Quotation from Anna Makarudze on the inspiration from PyCon Namibia to launch the Zimbabwe PyCons and secure a job at BriteCore

[5.8] PyAfrica website supporters page

[5.9] Python Software Foundation Annual Report Detailed Write-Up

[5.10] Python Software Foundation Board Resolutions

[5.11] Keynote by Danielle Procida and Aisha Bello "The Encounter: Python's adventures in Africa" EuroPython, 14 July 2017, YouTube video.