

<b>Institution: Keele University</b>
<b>Unit of Assessment: UoA11 Computer Science and Informatics</b>
<p><b>1. Unit context and structure, research and impact strategy</b></p> <p>Computer science at Keele is a small UoA, largely within the School of Computing and Mathematics. The School's historical focus is AI (especially neural networks) applications and evidence-based software engineering. The 2021 UoA11 return is characterised by significant growth, broadening of research themes and rapidly growing involvement in smart energy and transport sectors.</p> <p>The unit has made huge strides since REF2014 and is returning outputs from 15 staff with significant responsibility for research (15 FTE) plus two retired professors. This compares to 5 category A staff in REF 2014. Average annual research income has grown by 116% (to £233k from £108k) since REF 2014.</p> <p><b>Structure and its evolution</b></p> <p>All staff and postgraduate students (PGRs) are part of one or more thematic groups:</p> <ul style="list-style-type: none"> <li>• Artificial Intelligence (AI: nature-inspired computation, machine learning, data analytics)</li> <li>• Evolutionary Systems (ES: open-ended evolution, theoretical constraints on evolution, neuroevolution and behavioural evolution)</li> <li>• Software &amp; Systems Engineering (SSE: wearables, simulation, synthetic biology).</li> </ul> <p>Our structure is flexible, supporting widespread cross-theme and interdisciplinary collaborations. We have many cross-theme PhDs: for example, <b>Brereton</b> and <b>Andras</b> supervised pioneering work applying AI text mining in systematic reviews (<a href="https://doi.org/gf6h5m">https://doi.org/gf6h5m</a>); <b>de Quincey</b> and <b>Andras</b> supervised highly-cited research using ML in detection of malicious content in social media (<a href="https://doi.org/ff2j">https://doi.org/ff2j</a>).</p> <p>Our research on smart energy (<b>Fan, Cao</b>), which includes cross-discipline doctoral fellowships with industrial partners (Section 2) is aligned to both AI and SSE themes.</p> <p>Themes align with developing University and national priorities, and the staffing strategy reflects these priorities. For example, during 2020, two new cross-cutting AI/SSE themes emerged: Computational Health &amp; Biological Systems (<b>Woolley, Day, Misirli</b>: see Section 4 for collaborations), and explainable AI (<b>Ortolani, Woolley, Polack</b>).</p> <p><b>Collaboration and collaborative initiatives</b></p> <p>All returned staff have collaborations with other disciplines, SMEs, large companies, or health organisations (Section 4). All staff are supervising PGR students.</p> <p>UoA11 staff are Investigators on three major industry collaborations:</p> <ol style="list-style-type: none"> <li>1. The Keele Smart Energy Network Demonstrator (SEND), the largest cross-vector smart-energy network in the UK, underpins the University's objective to become carbon neutral by 2030. Funded (2017-21) by ERDF (£9.1m), Keele University (£1.5m) and BEIS (£4.7m), the project supports an interdisciplinary PhD programme. Academic Director, <b>Fan</b>, previously Chief Research Fellow with Toshiba Research Europe in Bristol, leads research on Internet of Things (IoT), smart grid, data analytics, and 5G communications. The programme supports Tenure Track research fellows: <b>Cao</b> (dynamic control / optimisation of multi-energy systems) and <b>Matthews</b> (UoA12: sustainable photovoltaics).       <ul style="list-style-type: none"> <li>○ In 2020, engineering partner Siemens plc announced a "global case study" based on SEND, whilst <b>Fan</b> leads the first UK-based MSc in Smart Energy Management.</li> </ul> </li> <li>2. Zero Carbon Rugeley, a sustainable smart local energy system design project for Rugeley,</li> </ol>

Staffordshire (2019-22, Innovate UK PFER: £1.4m + £1.5m from consortium partners), led by Engie plc., with Keele PIs from Institute for Sustainable Futures (Fogwill/Robinson): **Polack** and **Cao** are Co-investigators, communicating learning from SEND to support energy modelling.

- Building on Keele's global leadership in sustainability, **Polack** is academic lead for Simulate Live Lab (DfT/Adept, £1.9m), led by Staffordshire County Council (SCC) with Amey plc and Connected Places Catapult. Simulate manages 9 mobility and air quality trials with partner companies, and evaluation by Keele academics from many schools (<https://www.keele.ac.uk/business/businesssupport/simulate/>).

Further projects in smart energy and transport include: UrbanX (Innovate UK £316k partner: Qbots Energy, PI **Fan**); EPSRC PFER EnergyREV consortium (£9m; Keele Co-I **Fan** is cybersecurity lead; postdoc to be recruited 2021). The above initiatives support collaborations across Keele and beyond, representing a major UK and EU investment in the technology to underpin sustainability.

### Building from 2014

In 2014, UoA11 returned 5 staff. The 2014 strategy was to build on the strong reputation of existing research in *software engineering* and *computational intelligence/cognitive science*. This has been achieved, and our new vision is to continue to grow impact and visibility, aligned to national priorities (Section 2 outlines staff recruitment strategy).

The success of UoA11 since 2014 is underpinned by significant collaborative and interdisciplinary research, illustrated by the wide range of computer science and interdisciplinary topics covered in our selected outputs: theory and practical applications of large-scale data analytics/machine learning (supervised and unsupervised); theories of evolution and evolutionary computing; engineering design contributions as diverse as synthetic biology and smart energy management; evidence-based software engineering; use and analysis of systematic reviews; engineering of demonstrably fit-for-purpose simulations; pedagogic technologies; social media analysis; reconstruction from 3D models, design and analysis of health wearables.

Since 2014 in Software engineering, **Kitchenham** and **Brereton** (retired 2019) consolidated their international leadership of evidence-based software engineering, EBSE (Google Scholar "since 2015": Kitchenham over 20,000 citations, Brereton over 7,500); the EASE international conference they founded is now in its 25th year (<https://ease2019.org/previous-conferences/>). Their latest book (**Kitchenham, Brereton, Budgen** (2015) CRC Press ISBN: 9781482228656) underpins the tool suite which is the subject of our systematic review impact case study.

Over the REF period, through targeted recruitment, our software and systems engineering has developed new strands:

- Polack** and **Misirli**: research building on different areas of model driven engineering (e.g. <https://doi.org/f6qh8d>, <https://doi.org/f52k22>; <https://doi.org/f9tdq3>). **Polack** is a founder member of the internationally important York-based model driven engineering group (D. Kolovos, R. Paige). She leads pioneering work on software engineering of fit-for-purpose simulation (e.g. Stepney, **Polack** (2018) Springer ISBN 978-3-030-01938-9). **Misirli**'s research in computational synthetic biology is within an international collaboration that defined and manages the SBOL language (<https://sbolstandard.org/>; highly-cited 2014 Nature Biotechnology paper: <https://doi.org/f56pqq>; current version 3.0.0: <https://doi.org/ff5n>). **Misirli** contributed significantly to the language and tool interchange standards, repositories (<https://doi.org/gcwq8v>) and visualisation (<https://doi.org/ff5s>); personally contributing underlying mechanisms (<https://doi.org/ff5v>) and practical application of model-driven workflows in synthetic design (<https://doi.org/fdxf>). The research has spawned public repositories (e.g. [synbiohub.org](https://synbiohub.org), SEVA plasmid standardisation: <https://doi.org/ff5w>), and is used by open-source tools (e.g. Myers Research Group's SBOLDesigner (<https://sbol designer.github.io/>)).
- Woolley** and **De Quincey** have a wide range of research skills, loosely characterised as gadgets and usability: design and analysis of health/medical monitors, guidelines, wearables analysis and reliability of wearables (e.g., **Woolley** et al. <https://doi.org/fdz3>; **De Quincey** et

al. <https://doi.org/fdw8>). **De Quincey** also leads pedagogic data analytics and usability research (HEFCE Catalyst fund, 2016, £99,790, and JISC Learning Analytics Research Group, 2019, £19,880; e.g. <https://doi.org/fd2n>). His expertise in social media analysis (e.g. <https://doi.org/ff2j>) underpins collaborative research into the treatment of Muslims (e.g., AHRC AH/T004460/1/ £337,482, <https://doi.org/gg24nc>).

- **Woolley** leads a multidisciplinary collaboration on virtual 3D modelling and reconstruction, showcased in our [virtual cuneiform impact case study](#). The teams's technologies support 3D model acquisition, visualisation, interaction and reconstruction, and augmented reality, used in archaeological artifact reconstruction, interactive virtual museum displays and public outreach activities (<https://virtualcuneiform.org/ARMuseum.html>).

Since 2014, the computational intelligence/cognitive science (CICS) theme has split into two distinct research themes.

- Evolutionary Systems research (2014: **Channon**): **Channon** now leads a team that has established an international reputation in ALife and evolutionary computation. **Channon's** research includes: (1) his ongoing interdisciplinary collaboration (Section 4) developing new theory (e.g., extinction and evolution, in evolutionary computing and biology: BBSRC [£465,242](#) and [£268,176](#); <https://doi.org/bd7r>; <https://doi.org/cf8w>). (2) international leadership in open-ended evolution (OEE), co-founding the OEE workshop series (Section 4). The first OEE workshop report (<https://doi.org/bpqb>) reviewed OEE, revealing broad consensus on behavioural hallmarks of OEE plus broad hypothesized mechanisms, and led to a resurgence in OEE research internationally (<https://workshops.alife.org/oe2/>, <https://workshops.alife.org/oe3/>). The 2016 report was the most-downloaded ALife Journal paper in 2019 and is the most highly-cited paper ever in the ALife Journal. In 2019, Channon guest-edited the OEE special issue of the ALife Journal, which is the only double-issue of the Journal (Artificial Life 25(1) and 25(2), 2019).
- The wider Evolutionary Systems research includes **Stanton's** neuroevolution of robotic behaviour (e.g. <https://doi.org/59x>, <https://doi.org/ffm3>), leading to wider research in theory and practice of neuroevolution (e.g., <https://doi.org/ctfq>, <https://doi.org/ffzz>); and **Borg's** influential work on social behaviour evolution (e.g. <https://doi.org/b88c>).
- Neural networks and computational intelligence research (2014: **Day, Lam**): building on previous data analytics research, **Day** and **Mandal** research echo state networks and deep convolutional neural network approaches, with applications to time series, structural data, ultrasound, images and video. Examples of collaborative research (**Day, Kyriacou, Lam, or Mandal**) includes analysis of skeletal imaging (e.g. <https://doi.org/ggsh2x>), prosthetic control (e.g. <https://doi.org/ffz5>, <https://doi.org/fdn3>), hidden and visible defects in concrete structures (e.g. <https://doi.org/fdn4>, <https://doi.org/ffm9>; <https://doi.org/ffz6>), and a wide range classification problems using image or video data (**Mandal et al**, <https://doi.org/fd2h>, <https://doi.org/fd2j> ). **Andras** contributes novel theory and algorithms derived from neuroscience (e.g. <https://doi.org/fd2k>).

### Research and impact strategy

Our current research strategy, aligned to University Strategy, supports our rapidly growing research engagement and income. It is closely coupled to our impact strategy, and sees all staff engaged in research collaborations across disciplines, universities, industry and health organisations.

A key objective is to develop a sustained portfolio of funded research, which in turn will establish a community of postdocs to enhance the sustainability and resilience of research. There is already evidence of success, with 3 new postdocs recruited during 2020 (**Fan**, UrbanX; **de Quincey**, AHRC; **de Quincey**, data science research associated with OfS-funded MSc), and another starting in 2021 (**Fan**, EnergyREV).

In Artificial Intelligence (including nature-inspired computation, computational neuroscience, machine learning, data analytics, explainable AI), our strategic aims are:

- Strengthen and expand theoretical and applied AI in data-rich areas, specifically smart energy and transport

- Expand data analytics and statistical applications underpinning data science for biological and medical domains
- Maintain and expand structural and biological applications of our machine learning research

In Evolutionary Systems (open-ended evolution, incremental evolution, neuroevolution, behavioural evolution), our strategic aims are:

- Maintain and enhance our reputation in evolutionary systems research, in both the theory of incremental and open-ended evolution and applications to biological and engineered systems;
- Strengthen our robotics research, focusing on incremental neuroevolutionary strategies as drivers of evolutionary robotics and behavioural evolution;
- Expand our developing expertise in modelling social and cultural evolution.

In Software & Systems Engineering (wearables, simulation, synthetic biology, digital heritage), our strategic aims are:

- Evolve EBSE research in new directions, developing our expertise in engineering complex system simulation and user-centred design;
- Extend, through collaboration with other themes and disciplines, system and software engineering principles and practices to data analytics, medical systems engineering, and digital heritage, smart energy and transport;
- Grow the impact of our work on digital heritage, 3D visualisation, learning analytics, usability and health monitoring.

In addition, we are actively developing research that supports our growing data science teaching and the University's digital strategy. We aim to consolidate emerging research on ethical and explainable AI (above) aligning with professional policy work undertaken independently by our data science lead, Dr Allison Gardner, (with IEEE; BSI; charitable organisations -- Leverhulme, Chatham House, G20 women's forum; UN Rapporteur on impact of AI on vulnerable groups; with policy makers -- UK Select Committee on Artificial Intelligence, All Party Parliamentary Group STEM, Centre for Data Ethics). We anticipate future impact and international recognition in this area.

In relation to our large industrial projects in Smart Energy and Transport, our strategy aligns with National and University sustainability agendas. Our strategic aims are to:

- Build strong interdisciplinary research within the University's Institute for Sustainable Futures, showcasing Keele's demonstrator and live lab capabilities, consolidating the relevance and usability of the demonstrator/live labs to guide future (inter)national initiatives;
- Expand further our industrial partnerships and funding through active participation in energy, transport and sustainability initiatives from UKRI and others, and build on our participation in DERLAB, Energy Research Accelerator (ERA) and EnergyREV;
- Increase, and build research from, our "industry assist" roles in smart energy and transport.

### Research integrity

UoA11 is committed to open science. Gold or green open access is a requirement, supported both via the University Open Access Fund and school resources; staff include open access costs in all submitted research proposals. All outputs are available via the University's Symplectic repository and associated data management systems. Understanding of open science is now the focus of staff development across the School via workshops at Research Awaydays, with associated scholarship on data management and research ethics in data science. To further strengthen the rigour and integrity of our research, we are working with the University and Faculty research integrity champions on the development of robust data curation, and replicability of research (**Misirli**). Colleagues are actively involved in the School and Keele initiatives to ensure that research is conducted according to appropriate ethical and legal frameworks, obligations and standards. **Woolley**, the Faculty Ethics Director, and **Polack**, the School Research Director, provide guidance and oversight for staff and PGRs in relation to research ethics (e.g., use of the

University Ethical Oversight Committee's innovative risk-based ethical assessment process) and GDPR (e.g., Oct 2019: invited seminar by GDPR expert, Charlie Houston-Brown, RushKeep Solutions / BCS North Staffordshire Chair). Aligned to our developing research in bias and explainability in AI (**Ortolani**, Gardner), and our growing reputation in data science teaching, frameworks for data science ethics and integrity are becoming an important part of our research portfolio.

### Future strategic aims and impact

Our overall research impact stems from extensive collaboration, within academia, with companies and with health organisations. We are establishing ongoing processes, working with University and Faculty impact leads, to support early identification and enhancement of research impact, including developing the impact of our industrially important smart energy and data science research -- which align to University, regional, national and international priorities in sustainability and inclusivity. Our strategies encourage cultivation of partners for research in AI, smart energy and transport, health wearables and other medical computation, and user centred design. For example, AI researchers collaborate with civil engineering firms MWT Engineering Ltd and Arcadis Ltd. Machine learning applications on medical data has partnered University Hospitals of North Midlands (Stoke-on-Trent) and The Robert Jones and Agnes Hunt (RJAH) Orthopaedic Hospital (Oswestry). A major KTP (£250k: PI **Kyriacou**) applies business-critical data analysis with Bentley Motors. Our collaborations are elaborated in Section 4.

Looking to the future, we anticipate strategic growth in computational support for sustainability, notably in relation to smart energy and transport; continued development and growth in data science research including applied data analysis, explainable AI, bias in AI and other data analytics, and research integrity in data sciences. We expect broad collaborations across data-related research areas within Keele and the development of further academic and industrial collaborations in these strategically important areas.

## 2. People

### Staffing and staff strategy

Staffing strategy is embedded within, and complemented by, Keele's People Strategy (see REF5a). We are returning 15 category A staff and two retired professors (cf: REF2014: 5 staff). Eleven of these 15 staff joined since 2014, leading to significant evolution in strategy and research. Our strategy allows us to maintain balance in seniority, bring in strong early-career and experienced staff.

Since 2014, we have externally-recruited three professors: **Andras** (Newcastle), **Polack** (York) -- replacing Brereton, Kitchenham -- and **Fan** (Toshiba). **Channon** was promoted to Reader. Our 3 senior lecturers (SLs) are **Woolley** (appointed 2016, Birmingham); **de Quincey** (appointed 2015, Greenwich; promoted 2016) and **Kyriacou** (promoted 2019).

Four Computer Science staff were Early Career Researchers (ECR) on appointment (**Stanton** 2017, **Misirli** 2017, **Mandal** 2018, **Borg** 2018). **Stanton** and **Borg** were Keele postgraduates; **Misirli** was a postdoc at Newcastle; **Mandal** was a postdoc at A\*, Singapore. **Ortolani** (appointed 2018, from Palermo, Italy) is in his first permanent post; in 2017 he was awarded a Fulbright Scholarship (Missouri University of Science and Technology). **Cao** (recruited 2017, from Oxford) is an ECR in the Keele Institute for Sustainable Futures and SEND Research Fellow; he is Col on both UrbanX (PI **Fan**) and Zero Carbon Rugeley (Section 1) and has held a £7k Royal Society Grant (2019-20) and a National Natural Science Foundation China Grant (2015-17).

### Support for ECR staff

Our ECR support combines well defined expectations and active mentoring / support. Probation applies to all new staff, and mandates university training and induction. ECRs also take the Keele Higher Education Practice MA/PGDip and become HEA Fellows. **Polack** and **Andreas** mentor

first-grant submissions (e.g. by **Misirli, Mandal, Stanton**).

**ECR support examples.** **Borg** joined the academic staff in 2018, having contributed significantly to teaching activities alongside his PhD. He has received active support (from theme lead, **Channon**, and Research Director, **Polack**, for instance) to (a) achieve a REF output profile on social evolution and noise research; (b) establish the collaborations needed to progress his research, through local funding for visits and visitors, etc. **Misirli**, by contrast, already has significant collaborations and strong research output.; his support has focused on developing independence, exploitation of funding opportunities, widening publication outlets to develop research impact; in addition, senior staff are supporting development of **Misirli's** potential as a future research leader, with a goal of a leadership fellow application within two years. **Cao** is mentored by academically **Fan**, developing novel research in e.g. aspects of smart energy management and optimisation; **Polack** is supporting impact development by **Cao** and **Fan**, and contributing to development of **Cao's** research leadership ambitions (he has reached the interview stage of UKRI Future Leaders Fellowship competition: unfunded MR/T042761/1).

### Equality, Diversity, Inclusion (EDI)

The school is actively committed to inclusivity and holds Athena Swan Bronze (renewed October 2020), whilst the University's holds an institutional Athena Swan Bronze. The university's support for inclusion and diversity (including, for instance, a very active BAME staff group, an LGBTI Role Models & Allies Programme and strong diversity leadership within Faculties) is recognised by a Bronze Race Equality Charter Award, Level 2 Disability Confident Employer status and a positive Stonewall Workplace Equality Index ranking.

All recruitment uses positive action to encourage and support applications from underrepresented groups; interviewers must have up-to-date training in recruitment best practice and unconscious bias. Interview panels aim to include female and BAME representation, whilst respecting the need to avoid overloading underrepresented staff groups. BAME are strongly represented in applicants and interviews, and we typically interview 30-50% female candidates.

All 15 REF-eligible staff are currently on fulltime open contracts. The unit responds flexibly to changing staff circumstances. For example, one member became permanent, fulltime in 2019, having been recruited as fixed-term 0.3 FTE (2016), rising to 0.6 FTE (2018) as personal circumstances changed. Other examples of adjustments to respect personal circumstances from the last three years include at least 4 returned staff with specific adjustments of more than two months (ill health, end of life care, paternity/parental leave). If we had staff returning to research after maternity leave, there is open access to the Keele Academic (Maternity) Returner's Fund. Shorter-term flexible working is considered formally in annual performance reviews, but also as needed in consultation with Head of School or School Research Director. All such meetings continue online since March 2020, with active support for staff safeguarding and working from home.

Category A staff include 4 BAME and 2 female academics (Table 1.1.). IWe are returning two retired female professors. Ratios are comparable to the sector, but we have a higher proportion of women in senior roles.

Table 1.1. Diversity detail, Category A REF-eligible staff

		BAME	ECR on arrival	Lecturer / Senior Postdoc	SL / Reader	Prof.	Post 2014 arrival
<b>Total</b>	<b>15</b>	<b>4 (26%)</b>	<b>5 (33%)</b>	<b>8 (53%)</b>	<b>4 (26%)</b>	<b>3 (20%)</b>	<b>11 (73%)</b>
Male	13	4	5	8	3	2	9

Female	2	0	0	0	1	1	2
Post 2014	11	3	5	6	2	3	11

### Support for research and academic training

UoA11 is fully committed to Vitae's Concordat for Promoting Excellence in Research. As the proportion of research-active staff increases, research leadership and mentoring has grown. **Andras, Polack** and **Fan** joined with extensive research experience: **Polack** took University of York's award-winning research leadership programme, and all have undertaken Keele leadership training. **Polack** sits on Faculty Research Committee, guiding research strategy for Natural Science, whilst all three are in Keele Research Leaders' Network, which meets monthly to support and develop the University's research culture.

Expectations for all staff are defined in School Role Descriptors and formally discussed in annual probation or performance reviews. Between reviews, research staff discuss plans and goals informally with School Research Director at least once a year. Formal and informal reviews identify promotion candidates, and identify support and development needs, as well as identifying and supporting potential fellowship candidates and future leaders, e.g., signposting to EPSRC FLF, Springboard and Aurora. We anticipate at least two promotions to Reader / Chair, and several to SL within the next 3 years.

In addition to ECR support, above, more senior staff support staff identifying and applying for funding, and assist in develop academic and industrial collaborations; e.g., **Polack** supports **Woolley** and Gardiner in their career development. As noted in Section 1, **Woolley** (Faculty Ethics Director) provides extensive support on research ethics and GDPR, working closely with University and medical ethics staff. Staff are also supported actively by the University research support team (RaSE). Senior staff review all proposals, maintain an archive of highly-rated proposals, and support staff working on rebuttals, or reviewing rejections.

Our research leadership activities have identified new internal collaborations, such as **Day** and **Mandal** on structural monitoring data analytics; **Fan, Andras** and **Ortolani** on AI for smart systems; **Polack, Woolley** and **Misirli** on simulation.

The School has a research budget for consumables and travel, which is accessible by all staff, postdocs and PGRs, and enables researchers to attend key conferences and research meetings (e.g., attending annual ALife and Models conferences): the only eligibility criterion is some relevance to the School research portfolio. In addition, **Polack** oversees our many applications for University funding (Faculty Research Development (RDF); Faculty PhD scholarships; Institute for Keele Liberal Arts and Sciences Fellowship (ILAS), Keele Impact Fund (KIF)). Examples of funded activities include Keele events (e.g., **Misirli** 2018: UK Ontology Network; **Polack** 2019: Agent Based Modelling workshop; **Mandal** 2019: BCS Workshop on Emerging ML), and ILAS-funded research visitors (e.g., S. Power, Edinburgh Napier: **Borg**, 2018; E. Gehlken, Frankfurt: **Woolley** 2019-20). KIF grants have paid for consumables and outreach activity for 3D reconstruction, 2019-2020.

There are a minimum of 3 all-staff research meetings a year (since March 2020, incorporated in monthly online School meetings). All staff contribute to strategy, theme evolution, and promotion of funding opportunities. Research seminars (weekly in termtime) include internal speakers (PGRs, postdocs and academic staff) and visitors from Keele and beyond: notable examples include Susan Stepney (York Cross-disciplinary Centre for Systems Analysis: 2016), Emma Hart (Napier, Editor-in-Chief of Evolutionary Computation: 2020), David McKee (CEO and founder of Slingshot Simulation, 2019).

We maintain strong research relationships with retired staff, **Kitchenham** and **Brereton**, who continue to contribute advice and insights (e.g., on research strategy and PhD supervision). It is likely that 2-3 current staff will retire during the next REF cycle, with similar potential to continue contributing to research activities.

Through our industry links, a number of staff have active industrial roles. All the SEND research fellows (below) spend a day a week with their company sponsors, and KTP researchers have all been based at the participating company.

### **PGR recruitment and supervision**

Our total PGR population over the REF period is 80 FTE, with an annual average of 11.4 PGRs. We have seen a sustained rise in recruitment over the period: in July 2020, excluding submitted PhDs, we had 17 PGRs, with many more due to join after the REF cut-off. Our total PhD awards in the reporting period is 20, a 138% increase over REF 2014. Since 2017, we have had 3 to 5 awards each year, which will be exceeded in 2020-21.

All staff are supported in recruiting PGRs (e.g., through FindAPhD and social media channels), and all returned staff have supervised PGRs during the REF period.

The school's broad artificial intelligence and health-related research is particularly attractive to PGRs; with many recent recruits coming from industry or studying part-time alongside working in companies (including: Apple Retail Systems, Dell Healthcare, GE Renewable Energy, DeutscheBank). The percentage of female PGRs is at or above sector average (July 2019: 2/17), with BAME also well-represented (July 2019: 4/17). There is no significant difference in attainment across groups. Among the current cohort of PGRs, four have recognised disabilities, requiring adjustments to study conditions and other support. They are actively supported by School and Faculty PGR directors, who also provide advice and guidance to supervisors. PGRs are supported by the University disability services. Some PGRs have flexible working arrangements (including parental leave and remote supervision); during 2020, most PGRs received support for home working from the School, including provision of computer hardware and software. Remote supervision and online support groups have worked well.

The SEND project supports 16 industry-linked doctoral research fellowships, due to complete during 2021-22) at Keele (Table 2.1) and elsewhere (Table 2.2), with seven in Keele Computer Science (these 7 are included in statistics, above). The fellowship contract for each PGR includes an industrial partner, two academic supervisors, and full PhD registration, establishing a wide range of disciplinary and commercial links<sup>1</sup>.

*Table 2.1. Keele-based SEND doctoral fellowships and sponsoring companies*

<b>Company</b>	<b>School</b>	<b>Title</b>
Connexica Ltd	Computer Science	Augmented / Virtual Reality as Persuasive Technologies for Reducing Energy Consumption
Synetica Ltd		Blockchain for the Internet of Things
Add2 Ltd		Electric Vehicle Charging and Control
Assured Systems (UK) Ltd		Privacy-preserving federated learning for IoT
Astec IT Solutions Ltd		Data Analytics for Industrial IoT and Digital-Twins
Giosprite Ltd		Deep Reinforcement Learning for Smart Energy Networks

<sup>1</sup><https://www.keele.ac.uk/business/businesssupport/smartenergy/researchdevelopmentandinnovationprogramme/three-yearsresearchprojects/>. Details are from fellowship contracts.



Powelectrics Ltd		Anomaly detection for IoT Time- series
JDSE Ltd	Chemical & Physical Sciences	Passivation of Transport Cylinders for Low Concentration Gas Standards

Table 2.2. Other SEND doctoral fellowships and sponsoring companies

Company	University	School	Title
Beta Research Ltd	Huddersfield	Computing & Engineering	Transient Energy Storage Sources for Future Electrical Power Systems
H V D C Technologies	Huddersfield	Computing & Engineering	Grid-forming Virtual Synchronous Machine technique
Power Technologies Ltd	Lincoln	Engineering	MPC for Power-Constrained EV charging
DRM Technic	Staffordshire	Creative Art & Engineering	Measuring Particulate Emissions from Small Combustion Plant Process
Adelan Ltd	Aston	Engineering & Applied Science	Control Strategies for Micro-Tubular Solid Oxide Fuelcells
Lucideon Ltd	Warwick	Warwick Manufacturing Group	Flash Sintering of Ceramic Electrolytes for Solid-State Batteries
Environmental Essentials Ltd	Northumbria	Mechanical & Construction Engineering	Low carbon technology management and safety
Prime Hybrid Energy	Wolverhampton	Engineering	Battery storage in domestic applications and communal mini-smart grids

**Fan** leads the SEND doctoral fellowships as a doctoral training centre (DTC), with joint training and cohort meetings. We have a strategic objective of winning a funded DTC, focusing on AI for smart energy, transport, sustainability, data science (e.g. health or medical analytics): we have had several highly-rated but ultimately unsuccessful bids -- notably AI and smart energy, with Southampton (EPSRC, 2018).

In addition to registered PGRs, **Fan** supervises 2 visiting PhDs (China CSC), whilst **Woolley** and **Andras** have hosted Erasmus+ visiting PhDs.

External PhD studentships are summarised in Table 2.1. We have one current Faculty-funded student, and have had several partial Faculty scholarships in the past.

Table 2.1. Grants spend, PGR external funding, 2014-July 2020

Source	Short Title	start	end	Lead Supervisor	Spend
Iraq Min. High. Edu. & Sci.	Time Evolving Streams Analysis for SPAM Detection	9/17/2014	9/16/2017		51,000

Embassy of the United Arab Emirates	Information security and Human computer interaction	1/12/2015	1/11/2018	ANDRAS	53,100
NITDA	Text mining for systematic literature reviews in software engineering	2/23/2015	2/22/2018		51,000
University of Philadelphia (Jordan)	Testing large scale software on the cloud	9/29/2015	9/28/2018		57,000
Libyan Min. HE Sci. Res.	Issues in acceptance of VLEs for elearning	4/18/2016	4/17/2019	DE QUINCEY	52,798
University Hospitals of North Midlands	Guidelines for the Production of Medical Guidelines Mobile Applications	12/1/2017	11/30/2020		29,714

Keele's PGR Code of Practice mandates that PGRs develop a Personal Development and Learning Plan. Our School PGR Director (**Misirli**) coordinates internal training to complement University (Keele Doctoral Academy) and Faculty training (e.g., **Polack** leads training on research impact, and **Woolley** on research ethics and data management). External training is funded by the School and Faculty (e.g., 2 PGRs attended BCS HCI Statistics Masterclass, 2020). PGRs and their elected representatives engage proactively in creation and delivery of training activities; there are annual school, faculty and university PGR conferences (online 2020-21).

PGRs participate in all departmental research events contributing strongly to theme meetings. The success of our inclusive and supportive approach is evidenced by 2019 PRES (CS scored 91% overall, 98% on research skills, cf. University average, 86%).

#### Technical support and administration

Support for the School of Computer Science and Mathematics comprise 3.8 FTE technical support team (Section 3), and a full School administrative team complemented by four staff supporting industrial engagement.

<sup>1</sup><https://www.keele.ac.uk/business/businesssupport/smartenergy/researchdevelopmentandinnovationprogramme/three-yearsresearchprojects/>. Details are from fellowship contracts.

### 3. Income, infrastructure and facilities

During the REF period, our research income is £1.6m (202% increase from REF 2014). Average annual income has risen by 116%. This omits grants supporting PhD students, and grants where no spend had occurred by July 2020 (De Quincey: AHRC; Lam: University Hospitals of the North Midlands Trust).

The raw figures hide the extent to which funding supports collaborative research. For example, Channon's collaborations on theory and application of evolution have been supported by a series of BBSRC grants, whilst the Keele smart energy initiatives and collaborations are recognised by EPSRC (EnergyRev), BEIS/ERDF (SEND), Innovate/SLES (ZCR) and Innovate (UrbanX). Our success with large collaborative grants is allowing us to achieve our objective of recruiting a strong postdoctoral community, which, in turn, strengthens our ability to compete for grant funding.

**Kyriacou** and **Andras** lead an Innovate UK KTP with Bentley Motors valued at almost £250,000;

two further Innovate UK KTPs were completed during the period (**de Quincey** et al, KBC Process Technologies Ltd: 2016-18, £130,000; **Lam** et al, Wood Mitchell Printers: 2015-17, £175,000).

Like most computer science departments, our main funding target is EPSRC. However, because all research-active staff are engaged with interdisciplinary and non-academic collaborators, we are not prescriptive. For example, in the 12 months to October 2019, we submitted 7 proposals to EPSRC (“first grant”, responsive mode and call bids), 2 bids to BEIS, and one bid each to: BBSRC (responsive mode), Innovate UK, British Council, British Computer Society, Cultural Evolution Society, Yoti Ltd, Sarcoma UK, Cancer Research UK, Alan Turing Institute, Nvidia and Amazon; during the same period, **Fan** and **Polack** were academic leads in partnership bids to Industrial Strategy Fund and to DfT/Adept.

For PGRs, in addition to the 8 SEND fellows, we had one [BBSRC](#) case studentship £92k (**Lam**: 2013-17) and one EPSRC doctoral training studentship (**Kyriacou**: Regenerative Medicine CDT). Overseas and other awards are shown in Table 3.2.

### Infrastructure and Facilities

Staff and PGRs are co-located, sharing facilities with Mathematics. All facilities are available 24/7. During 2020, we have worked hard to maintain virtual machines and online access to all facilities, and to maintain interaction and research theme meetings, PGR meetings, and online PGR supervision.

In addition to University-supported research computing, we host:

- private vScaler cloud, purchased with School and Faculty funds (£25,000) and maintained by vScaler/BIOS IT <sup>2</sup> (valued at ~£5,000 per annum), supporting AI/data analytics and cloud systems research (e.g., Ahmad, **Andras**, J. Cloud Computing (2019) <https://doi.org/ggtz94>);
- CUDA GPU cluster (512 virtual CPU cores, GPU compute capacity 256 teraflops: £100,000 investment within REF period), supporting data analytics, evolutionary systems research and simulation.

The cloud and cluster are used by other schools (e.g., medicine, life sciences, psychology, physics & chemistry), independently and in collaboration with UoA11 staff. Access is free for staff and student research.

Other specialist teaching and research facilities include:

- state-of-the-art games lab, sponsored by Overclockers UK (~£60,000: 24 machines, plus accessories, maintenance and upgrades);
- virtual-reality lab;
- flexible research and meeting room that houses a robot lab with full camera tracking and simulation capability, and a makerspace (~£40,000).

The robot lab has Vicom camera tracking and a range of flying and walking robots. We have two 3D printers and a 3D scanner, primarily used in robotics and 3D model acquisition / reproduction (see virtual cuneiform impact case study). Our makerspace has Arduinos, Lego Mindstorm, and other “starter” robots,. Makerspace, VR and Overclockers’ Lab support significant outreach: e.g. we have a popular student-led robotics group which is enabling new directions in teaching and research, whilst the Overclockers’ Lab is a unique facility in the Stoke area.

We have full access to SEND data (via Siemens’ Digital Energy Management System and “Mindsphere” platform), to be complemented during 2020-21 with transport livelab demonstration facilities and data (Simulate). All are available to any researcher, subject to ethics, data protection and curation arrangements. In addition, our collaboration with medical researchers and links to hospital research give us access to medical and health data, and associated domain expertise.

<sup>2</sup> <https://www.vscaler.com/vscaler-empowers-teaching-keele-university/>

Our research facilities are maintained by the research software and hardware technical team, jointly with academic staff (**Stanton, Misirli, Channon**) to maximise usage and usability.

A strategic objective is to build on our ever-widening industrial and academic links, working with the University to achieve its Strategy of making Keele a regional leader in digital services, teaching and research (a new digital centre will open in 2022). We also plan to create digital simulation and visualisation facilities to complement the smart energy demonstrator and transport livelab facilities at Keele, widening our impact on the social and environmental sustainability agendas for which Keele is famous (e.g., as world leaders in sustainable education, behavioural analysis and behaviour change; policy change).

#### 4. Collaboration and contribution to the research base, economy and society

A notable feature of the research conducted by UoA11 staff is that almost all is undertaken in collaboration with companies, health trusts, and/or other academic disciplines. This is apparent in our selected outputs and case studies.

##### Collaborations related to Smart Energy and Transport

Keele is a sought-after partner for industry in the fields of smart energy and transport, with significant and growing impact on the sustainability agenda nationally and internationally. For instance, the key partnerships detailed in Section 1 include:

- The Smart Energy Network Demonstrator (SEND: **Fan, Cao**): industrial and academic partners are listed in Tables 2.1 and 2.2. SEND researchers have a significant practical partnership with Siemens Plc., the lead contractor.
- Zero Carbon Rugeley (Cols **Polack, Cao**: Innovate PFER) is a consortium led by Engie PLC (full list of partners: <https://www.rugeleypower.com/zero-carbon-rugeley-project>). Like SEND, the research includes collaborations across the Keele Institute for Sustainable Futures.
- Simulate Live Lab (**Polack**, DfT/Adept) is the only one of the eight DfT-funded live lab projects to have a full academic partner, alongside Staffs CC, Amey plc and Connected Places Catapult, and supporting nine industry-led feasibility projects (for full list, see <https://www.keele.ac.uk/business/businesssupport/simulate/>)
- **Fan** and **Cao** work with Qbots Energy (Innovate UK: UrbanX project), which is implementing academic research such as **Cao's** battery energy optimisation framework (<https://doi.org/fdpb>).
- **Fan** is also cybersecurity lead on the Core EnergyREV (EP/S031863), a consortium of 12 universities, led by Strathclyde.
- **Fan** maintains links with Toshiba, and with a range of academic partners in smart energy and transport, e.g., Oxford and Leeds (<https://doi.org/fdpc> <https://doi.org/fdpc> <https://doi.org/fdpc>) Aston and Sheffield (<https://doi.org/qc79q8>).

##### Collaborations related to health and medicine

We have extensive collaborations within Keele medical and related disciplines and with health trusts/hospitals, including pioneering work on data analytics, health monitoring, training, and various forms of app (**Andras, Day, de Quincey, Lam, Kyriacou, Mandal, Woolley**).

The research reported in REF2014 and 2014 impact case studies (**Lam, Day**) continues, with partners from Oswestry ([Orthopaedic Institute Ltd/RJAH](https://www.orthopaedicinstitute.co.uk/)) and University Hospital North Midlands. The work on analysis of time series and visual medical data is detailed in Section 1, representing a long-term collaboration with staff of the former Keele Institute for Science and Technology in Medicine, now at Aberdeen University.

North Midlands Trust Charity funds research on app-based clinical care guidelines, (see Sections 1, 3 and below: **de Quincey**: <https://doi.org/fdw8>). The research is a collaboration with Royal Stoke University Hospital, and surveying many other health trusts, then applying usability design

expertise to create a bedside clinical guidelines app, which is being rolled out to 14 Trusts in 2021, with a further funded postdoc to support evaluation and development. This research collaboration is already generating interest and impact in clinical organisations.

North Staffs Medical Institute is funding data analysis research due to start by 2021 (**Lam**: partner Great Ormond Street Respiratory Sleep Unit).

**Woolley's** research on the design and analysis of health-related devices led to her participation in Ambient Assisted Living EU COST Action "AAPELE": <https://www.it.pt/Projects/Index/1921> (2013-17); she continued to build on this collaboration in analysis of wearable health technology (Universidade da Beira Interior and Universidade Lusófona de Humanidades e Tecnologias), along with a PhD visitor from Georgian Technical University and Keele School of Health and Rehabilitation Keele, (e.g. <https://doi.org/fdn6>). Woolley's groundbreaking research on adrenaline injection training was a collaboration University Hospitals of Leicester NHS Trust, and Birmingham City (<https://doi.org/fdn7>), whilst in 2017 **Woolley** and her collaborators at Manchester Metropolitan, Birmingham, and University Hospitals, Birmingham presented a collection of research under the title "the quantitative outpatient", which received the best poster presentation award at European Federation for Medical Informatics Conference.

### Collaborations in theory and practice of evolution

Our Evolutionary Systems team has a number of ongoing collaborations which reflect its importance in open-ended evolution and evolutionary robotics.

**Channon** (see also Section 1) has ongoing collaborations in evolutionary theory, with applications in biological, health and environmental research, with Manchester (Environmental Research Institute; Evolution & Genomic Sciences) and Middlesex (Science & Technology). The research is summarised in papers and led to or was funded by a series of grants. For example, <https://doi.org/skb> reports research funded 2010-2013 by **EPSRC** £423k. Subsequent research funded by **BBSRC** £465k, 2014-2017 and **BBSRC** £268k, 2015-2018 is published in e.g. <https://doi.org/bd7r> -- 2016, Journal of Mathematical Biology; <https://doi.org/cb9s> --2017, PLOS Biology; <https://doi.org/cf8w> -- 2017, Scientific Reports; <https://doi.org/cst8> -- 2018, ISME; and <https://doi.org/ctm6> -- 2018, Heredity.

**Channon's** agenda-setting research on Open-Ended Evolution includes collaborations with Bedau (Reed College, USA; President of the International Society for Artificial Life 2001-2015) and Taylor (Monash University, Australia). The team founded the International OEE Workshop (<https://workshops.alife.org/oeel/>. Details in Section 1).

In evolutionary robotics, **Channon** and **Stanton** are part of a team led by F. Iida (Cambridge Bio-Inspired Robotics Lab) that has a Leverhulme Trust proposal accepted for full application (2020): the research explores open-ended evolution of physical robots. Meanwhile, **Stanton** has a longterm collaboration with J. Moore (Grand Valley State University) on incremental evolutionary robotics (<https://doi.org/cwwj>, <https://doi.org/ffm3>, <https://doi.org/fdz9>, <https://doi.org/ffm4>).

In social and behavioural evolution, **Borg** has two key collaborations: with S. Power, Edinburgh Napier (Keele ILAS Visiting Fellow 2019) on social evolution (e.g. <https://doi.org/fqc9>) ; and with M. Grove, Liverpool Archaeology on models of noise and historical evolution (e.g. <https://doi.org/fgcd> -- ALife conference best paper of 2020).

### Other significant academic collaborations

The following summary exemplifies the range of our other collaborative research. Many more collaborations are noted in earlier sections and evidenced by co-authorships.

- **Andras'** neuroscience work on voltage-sensitive dyes is an ongoing collaboration with Newcastle University (Neuroscience Institute, Digital Interaction Group, Electronic Engineering), and a wider network including Imperial College and South East University, China, (e.g. <https://doi.org/fdxb>).

## Unit-level environment template (REF5b)

- **De Quincey** has a long-running collaboration with Keele Media and Communications (£337k [AHRC Grant https://doi.org/gg24nc](#)). He is also an authority on technology in pedagogy, where he works primarily with Warwick Mathematics (JISC grant: <https://analytics.jiscinvolve.org/wp/2020/07/08/using-analytics-to-enhance-student-support-and-improve-learning/>)
- **Mandal**'s long-running collaboration with A\*Star, Singapore (e.g. <https://doi.org/fdxc>) and with IIUT, Bhubaneswar, India (e.g. <https://doi.org/fdxd>), has applied his machine learning and vision analysis technique to many data sets. Mandal is developing partnerships with the Keele Medical School, which funded a PGR scholarship and postdoc with P. Yeates, 2020-23. The same analysis approach is being applied to analysis of civil structures with Arcadis Ltd, Birmingham, UK (e.g., unfunded EP/V006061).
- **Misirli**'s significant work on computational synthetic biology (Section 1) sees collaboration with the ongoing £5m [international consortium](#) led by Imperial College and Newcastle University Centres for Synthetic Biology. His many contributions to the SBOL language and to synthetic biology repository and workflow frameworks have collaborators such as Universities of Washington, Boston and Utah in US (<https://doi.org/fdxf>, <https://doi.org/gcwg8v>), as well as the academic and industry partners listed on the SBOL website, <https://sbolstandard.org/>.
- **Ortolani** maintains his collaborations with Universities of Missouri Science and Technology and Kentucky, US (e.g. <https://doi.org/fdw7>, <https://doi.org/gdwffd>) and University of Palermo, Italy (e.g. <https://doi.org/fdw6>).
- **Polack**'s work on simulation fitness for purpose and software engineering builds on collaborations with York Biology, Medicine and Electronic Engineering (e.g. <https://doi.org/fdw5>), Computer Science (e.g. <https://doi.org/fdw4>) and others (e.g. <https://doi.org/f7pd87>, <https://doi.org/ff7v>). Recent collaborations include King's College, London (e.g. <https://doi.org/fdw3>), McMaster and Toronto, Canada (<https://richpaige.github.io/uncertainty2020/>, <https://doi.org/ggqrvn>).
- In addition to her health-related collaborations, above, **Woolley** works with Manchester Metropolitan, University of Nottingham Ningbo, China, and Institut für Archäologische Wissenschaften, Goethe-Universität, Germany, on acquisition of 3D models and virtual reconstruction (e.g. <https://doi.org/fdw2>) the research underlying the virtual cuneiform impact case study.

**Major funded networks in which we participate include**

- EPSRC EnergyRev consortium (**Fan**, above)
- EPSRC MDE-Net £463k (Polack) led by King's College, London and Edinburgh University.
- EU DERLAB (**Fan**) (<https://der-lab.net/>): EU consortium of leaders in distributed energy research, which aims to develop technology requirements and quality criteria.

Also, arising from our major industrial collaborations in smart energy and transport, **Fan** and **Polack**, respectively, represent Keele on (a) ERA network: the Midlands research centre of excellence in energy and sustainability and (b) the Midlands innovation transport group.

- In October 2020, through the ERA network, Keele became a partner in the new Centre for Postdoctoral Development in Infrastructure, Cities and Energy (C-DICE: Research England funded, £4m), which will further enhance our smart energy and transport research and collaborations.

**Wider contributions to research and economy**

Our staff make a significant contribution to the discipline. Academics within the unit serve on many research bodies. Examples from the current REF period include the following:

## UKRI:

- EPSRC Full College members: **Andras**, **Brereton**, **Channon**, **Fan**, **Polack**, **Woolley**: in 2019, **Woolley** received a EPSRC review commendation; she served on CDT panels in 2018; **Channon** serves as a panel and interview panel member
- BBSRC proposal reviews: **Channon**

Other UK funding organisations:

- Royal Society Panel Member: **Andras**
- Carnegie Trust S.E.T., Research Assessor: **Polack**
- UK Commonwealth Scholarships Commission, Academic Adviser: **Lam**

International funders:

- EU H2020 reviewer: **Andras**
- Portuguese Foundation for Science and Technology reviewer: **Fan**
- Qatar National Research Fund, reviewer: **Fan**
- Research Council of the Sultanate of Oman, reviewer: **Fan**
- Innovation Funding Agency of Belgium, reviewer: **Fan**
- Dutch Research Council (NWO), Complexity Panel (2017-18): **Polack**
- FWF Austrian Science Fund (2017, 2019), reviewer: **Polack**
- FIT - IT Austrian Research Promotion Agency (FFG) panel member: **Andras**

Examples of our current editorial roles include: **Andras** (Elsevier Cognitive Systems Research); **Fan** (IEEE Access; Associate Editor: IET Smart Cities). **Fan** was also guest editor of a Special Issue of Journal of Network and Computer Applications on “Smart World Systems, Applications, and Technologies”. **Channon** was guest editor of ALife Journal special editions on open ended evolution (Section 1).

Examples of research invitations during the REF period include:

- **Andras**: keynote to Trust in Intelligent Machines, Edinburgh, 2018
- **Channon**: Invited talk, Robotics Seminar Series, University of Cambridge, 2019
- **de Quincey**: Keynote at Academic Practice and Technology conference 2017 <https://aptconference.org.uk/index.php/apt/apt2017/schedConf/overview>
- **de Quincey**: “Who speaks for Muslims?” British Academy panel discussion. Audio: <https://www.britac.ac.uk/audio/who-speaks-muslims> 2018
- **Fan**, invited speaker at UK-KSA Workshop on clean energy and AI, 2019; Energy Live Expo, London, 2019; UK-UAE Science Collaboration Symposium on Clean & Renewable Energy, 2018; China-UK Energy research partnership symposium (USTB, Tsinghua, JITRI), Jan. 2020
- **Fan**: Invited panellist, PFER showcase, London, 2020
- **Fan**: Invited lecturer, ICET (International clean energy talent programme), Sweden, 2019
- **Polack**: Dagstuhl seminars invited participant (2018: no.19481, 2019: no.18491);
- **Polack**: Shonan seminar invited participant (2020: no.168 -- COVID postponement to 2021)
- **Polack**: Festschrift invited chapters for Springer: *From Astrophysics to Unconventional Computation* (<https://doi.org/ff7r>); and Journal of Object Technology Special Issue 19(3) dedicated to Martin Gogolla (<https://doi.org/ff7v>)
- **Polack**: Member of Scientific Advisory Panel, Premier project, 2020-2026 (EU Partnership for Health IMI, grant 875508: <https://imi-premier.eu/>)
- **Stanton**: “Science Lives Here” event, A generalist AI panel, Royal Institution, 2019: <https://soundcloud.com/royal-institution/a-generalist-ai-ri-science-podcast-45>
- **James Mitchell**, final year PGR working clinical guidelines usability and app support (supervisor: de Quincey) is invited Vice-Chair of the International Medical Informatics Association Students and Emerging Professional SIG (2019-21) (<https://imia-medinfo.org/wp/student-and-emerging-professionals-special-interest-group-sep-sig/>) and Early Career Lead for BCS Health and Care.

Other awards and recognition include:

- In 2019, **Kitchenham** was recipient of *IEEE CS TCSE Distinguished Women in Science and Engineering (WISE) Leadership Award*.
- In 2014, **Kitchenham** received the *ACM SigSoft Impact Award* for her seminal 2004 paper Evidenced-based software engineering (<https://doi.org/crc8n5>)
- In 2016, **Polack** was awarded an *ACM Ten Year Most Influential Paper Award* for 2006 MoDELS conference paper, Merging Models with the Epsilon Merging Language by Kolovos, Paige and **Polack**. (<https://doi.org/cssn9v>)

- *BCS Health & Care Scholarship Award 2019*: James Mitchell (PhD, supervised by **De Quincey**): clinical guideline delivery.
- Best paper awards include: **Borg** et al., ALife Conference, 2020: <https://doi.org/fgdc>; **Misirli** et al., IEEE Symposium on Computational Intelligence and Bioinformatics and Computational Biology, 2014: <https://doi.org/fgk2>; and **Polack** et al., Conference on Operations Research and Enterprise Systems 2016: <https://doi.org/ffm7>.

Some of the journals for which staff reviewed repeatedly during the REF period are: ALife Journal (**Andras, Channon, Polack, Stanton**); SOSYM Journal (**Polack**); IEEE Trans. Neur. Netw. Learn Sys. (**Andras**); IEEE Trans. Intelligent Transportation Systems, and IEEE Trans Image Processing (**Mandal**).

Some selected examples of our international conference activities include:

- Artificial Life Conference (ALife): Regular PC / reviewers throughout REF period: **Andras, Borg, Channon, Polack, Stanton**.
- ALife Workshop co-organisers (three international Open-Ended Evolution Workshops; four international Social Learning and Cultural Evolution Workshops): **Channon; Borg, Andras**
- Models Conference: PC / reviewer throughout REF period; PC Member for the MODELS ACM Student Research Competition-track (2020), EduSymp@Models (regularly): **Polack**. (Polack also reviews regularly for conferences such as ECMFA and ICSE.)
- Models Workshop co-chair: Uncertainty@Models workshop (2020); Models EduSymp (2019) : **Polack**
- ACM Digital Health Conference PC and Poster/Demo Chair: **De Quincey** (2015, 2016)
- IEEE Smart World Congress Programme Chair: **Fan** (2019)
- International Workshop on BioDesign Automation: **Misirli**, organiser (2016) and regular PC member.
- Emerging Research in Electronics, Computer science and Technology conference, advisory committee and invited speaker (2018): **Mandal**.

Professors **Kitchenham** and **Breton** founded the international EASE conference, and have been involved in chairing, PC and organisation throughout its 25-year existence.

We are also committed to growing Keele's profile by hosting events and conferences. In addition to events noted elsewhere, Keele would have hosted 2020 BCS HCI Conference (Chair: **Woolley**; organising chairs: **de Quincey, Misirli, Ortolani, Mandal**), the national (and increasingly international) showcase for the human interface of computer science. Due to Covid-19 the conference has been rearranged to take place in Keele in 2022.

<sup>2</sup> <https://www.vscaler.com/vscaler-empowers-teaching-keele-university/>