

## Impact case study (REF3)

<b>Institution:</b> University of Plymouth		
<b>Unit of Assessment:</b> UoA10		
<b>Title of case study:</b> Increased Pupil and Public Participation with the Mathematical Sciences through School Taster Days and Plymouth Argyle Football Club		
<b>Period when the underpinning research was undertaken:</b> 2017- 31.12.20		
<b>Details of staff conducting the underpinning research from the submitting unit:</b>		
<b>Name(s):</b>	<b>Role(s) (e.g. job title):</b>	<b>Period(s) employed by submitting HEI:</b>
Dr Matthew Craven	Lecturer in Applied Mathematics	2013- present
Dr John Eales	Deputy Head of School	1990 - present
Dr Luciana Dalla Valle	Associate Professor of Data Science and Statistics	2011 - present
Dr Jenny Sharp	Lecturer	1997 - present
Dr Julian Stander	Associate Professor	1993 – present
<b>Period when the claimed impact occurred:</b> 2016-31.12.20		
<b>Is this case study continued from a case study submitted in 2014?</b> N		
<p><b>1. Summary of the impact</b> (indicative maximum 100 words)</p> <p>The Centre for Mathematical Sciences (CMS)'s research has led to increased engagement and involvement with mathematics and science for thousands of pupils and hundreds of teachers, so raising pupils' aspirations and interest in science, technology, engineering and mathematics (STEM). In addition, CMS research has increased the public's contact with applications of Data Science through extensive contributions to Plymouth Argyle Football Club's (PAFC) website and programme, outreach publications with international coverage, and a BBC radio programme reaching one million listeners.</p>		
<p><b>2. Underpinning research</b> (indicative maximum 500 words)</p> <p>Relevant CMS research represents new, ground-breaking methodological and applied work in Bayesian inference and its applications, mathematics and statistics pedagogy, and Big Data analysis.</p> <p>Standar and Dalla Valle's research used Bayesian copula models to analyse paediatric ophthalmic data from nearly 3000 children, providing insights about the processes which determine transformations in sight as children age and an innovative tool that enables clinicians to identify children with unusual sight who would otherwise be missed [3.1]. Standar and Dalla Valle then used Bayesian survival analysis in the context of historical data sets, presenting insights about changes in longevity over time and producing interesting teaching material including Lexis diagrams illustrating the results of Bayesian inference [3.2]. Subsequently, Standar developed a Bayesian change-point analysis methodology in a geoscience context that demonstrated that the geographic spread of marine calcifiers was driven by both seawater chemistry and temperature [3.3]. This Bayesian change-point research informed a study by Eales and Standar of changes in English league football since the foundation of the Football League in 1888, which provided a better understanding of the decline in English football before the World Cup victory in 1966 and its subsequent improvement [3.4].</p>		

CMS has also made wide ranging and important research contributions to mathematics and statistics pedagogy. For example, Craven and Sharp analysed whether a university Foundation Year provided an enhanced transition to mathematics degrees compared with the traditional A-level route [3.5]. This was important as the transition from school mathematics to university-level STEM courses is often problematic, leading to issues with student satisfaction and retention sometimes referred to as the “Mathematics Problem”. Specifically, Craven and Sharp examined a partially flipped learning approach aimed at improving Foundation Year retention and enhancing the mathematical knowledge of those progressing to undergraduate study. This research into HE pedagogy complemented both [3.2] which discussed how the teaching of statistical topics such as Bayesian survival analysis can be enhanced by focusing on innovative applications and the prize-winning research by Stander and Dalla Valle in [3.6] (Jackie Dietz Best Journal of Statistics Education Paper Award). [3.6] discussed our experiences of teaching an intensive Data Science module, with topics including data manipulation, data visualization and the importance of reproducible research. It also provided four lesson plans.

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

3.1, 3.2 & 3.5] are submitted to this UoA. [3.6] won the *Journal of Statistics Education* Best Paper Award in 2017.

- 3.1 **Standar, J., Dalla Valle, L.**, Taglioni, C, Liseo, B., Wade, A. and Cortina-Borja, M. (2019) Analysis of paediatric visual acuity using Bayesian copula models with sinh-arcsinh marginal densities. *Statistics in Medicine*, 38, 3421–3443. DOI: <https://doi.org/10.1002/sim.8176> [Impact factor 1.847 (2018)]
- 3.2 **Standar, J., Dalla Valle, L.** and Cortina-Borja, M. (2017) A Bayesian survival analysis of a historical dataset: how long do popes live? *The American Statistician*, Teachers Corner, 72, 368–375. DOI: <https://doi.org/10.1080/00031305.2017.1328374> [Impact factor 5.381 (2018)]
- 3.3 Eichenseer, K., Balthasar, U., Smart, C., **Standar, J.**, Haaga, K. and Kiessling, W. (2019) Jurassic shift from abiotic to biotic control on marine ecological success. *Nature Geoscience*, 12, 638–642. DOI: <https://doi.org/10.1038/s41561-019-0392-9> [Impact factor: 13.566 (2019)]
- 3.4 **Statso, Standar, J.** and Cortina Borja, M. (2020) Has English league football become less exciting? <https://www.significancemagazine.com/sports/693-has-english-league-football-become-less-exciting> Please note that **Statso** is the pseudonym of **Dr John Eales**, submitted to this UoA, when he writes articles about football statistics for the Plymouth Argyle Football Club website or match programmes.
- 3.5 **Craven, M. J.** and **Sharp, J.** (2018) The “Mathematics Problem”: A Plymouth foundation year case study. *Journal of the Foundation Year Network*, 1, 23–35 (<https://jfyn.co.uk/index.php/ukfyn/article/view/17>). [New, bespoke journal. Over 90 article downloads overall. International reach, with views from Belgium, China, Germany, Russia, Sweden, UK, USA.]
- 3.6 **Standar, J.** and **Dalla Valle, L.** (2017) On enthusing students about Big Data and social media visualization and analysis using R, RStudio and RMarkdown. *Journal of Statistics Education*, 25, 60–67. Lesson outlines presented as Supplementary Material. DOI: <http://tandfonline.com/doi/full/10.1080/10691898.2017.1322474> [Impact factor 1 (2020)]

### 4. Details of the impact (indicative maximum 750 words)

The teaching of mathematics in school and HE frequently fails to engage learners. In schools there is a shortage of real-life examples to illustrate the subject’s relevance, and this can lead to a lack of interest and retention in the subject. Any failure to engage pupils means that children may be discouraged from studying STEM. There are also clear benefits from increasing public engagement in mathematics and science at all ages. CMS has contributed to tackling these participation issues through a large, research-based schools

programme, and through public engagement, including collaboration with PAFC. This has increased pupils' understanding and enjoyment of STEM and generally raised awareness of the Mathematical Sciences.

### **Increasing pupil engagement with the Mathematical Sciences**

UK businesses have warned of a growing skills shortage in STEM, which may cost £1.5 billion annually due to training requirements and unfilled vacancies. Many young people see STEM as irrelevant due to the academic nature of teaching in schools. Enhancing pupils' Science Capital (SC), defined as the sum of all the science-related knowledge, attitudes, experiences and resources that individuals accumulate, is of vital importance. SC is known to be an important factor in enhancing individuals' life chances. As over 20% of young people have low SC, CMS has used its research to increase SC by creating activities that deepen pupils' curriculum knowledge and that raise their interest, engagement and aspirations.

For example, Stander and Dalla Valle's research [3.1] on identifying children who have unusual eyesight, and who therefore need clinical intervention, was used to create a schools workshop. Pupils can easily relate to this research and were taken through computer-based exercises that allowed them to apply the research methodology to identify children with sight anomalies. To evaluate this activity's success, 96 pupils attending a 2019/20 Year 10 Taster Day completed a questionnaire. They experienced an increase in their understanding of mathematics (84%) and enjoyed seeing research (83%). A majority said that being exposed to this research had increased their interest in mathematics (57%), whilst 39% reported an increased likelihood of studying subjects related to mathematics. Corresponding percentages for a Year 12 Taster day based on 18 pupils are 88% (understanding), 100% (enjoyed), 50% (interest) and 44% (studying) [5.1]. When followed up after around two years, attendees at a 2018 Year 10 Taster Day provided the following reflections: "The time at Plymouth University was a unique experience...The teachers at the university demonstrated, with great understanding, ideas about mathematics that blew my mind. They showed me a new way of looking at the world... and a different way maths could be used and applied in a situation. At the end of the day, I was inspired by the events I had seen, which I feel impacted my future, as I am now applying for apprenticeships in a maths/science field of work." Similarly, a teacher reported: "The sessions gave students the chance to see a different perspective on many of the mathematical concepts they learn about in school and gave them the opportunity to delve deeper into areas of maths that they were interested in. The students came away from the sessions enthused towards the possibilities that studying maths can create for them". [5.2]

We strategically target under-achieving schools for all our Taster Day and similar activities. We estimate that 20% of the students who attend our events are "first generation" as 50% come from postcode areas in the lowest two quintiles for HE participation. In 2018/19 CMS Taster Days were attended by over 300 pupils who were asked to rate on a 0 to 5 scale how challenging they found their research-informed activities (average rating, 3.8) and how much they enjoyed them (4.4). Pupils were pleased to see a "different kind of maths". Sharp and others gave seventeen Children's University Masterclasses and seven Royal Institution presentations. The whole programme involved 2600 students and 230 teachers from 200 schools. CMS also offers research-based activities for summer work experience pupils. One of these activities led to a pupil producing a publication in *Significance* about visualizing regional data which has received over 30,000 views. There has, of course, been disruption to our more recent pupil engagement programmes due to Covid-19.

### **Increasing public awareness of the Mathematical Sciences**

CMS research reaches countless people during the football season, resulting in a greater public awareness of the applications of the Mathematical Sciences. Research on data presentation including [R6] and modelling changes in the English football league [3.4] has underpinned over 50 articles for the PAFC web site [5.3] and 100 contributions to the PAFC match programme *The Pilgrim*, selling 1000 copies at each of 23 home matches per season, written by Eales (pen-name Statso). These '*For the Record*' articles have contributed

to *The Pilgrim* being named the top programme in Sky Bet League One in 2018 and 2019 [5.4]. The Midland Programme Club stated that there was an “*Outstanding amount of stats throughout the issue – credit to the stat man [Eales]!*”. This has also resulted in PAFC’s content team being shortlisted in the Best Football Club category of the Football Content Awards 2020 [5.5]. Richards, the Premier Programme Editor, confirmed [5.6] that *The Pilgrim* had been awarded 9/10 for original content and for 8/10 for design and layout. In a questionnaire about *The Pilgrim*, 27% of 98 fans stated that ‘*For the Record*’ was their favourite feature. Eales has also contributed statistical material to the Jack Leslie Campaign which in the spirit of the BLM movement aimed to celebrate diversity and combat racism, and which raised over £100K to honour a PAFC footballer denied an England cap because he was black [5.7].

In 2016, the BBC picked up CMS research on the analysis of papal longevity [3.2]. This led to Stander taking part in their *More or Less* programme which reaches around one million listeners per week, as the lead story. Ed Davey, the BBC journalist, wrote that *More or Less* is “the BBC’s flagship statistical programme” and considered one of the “Crown Jewels of Radio 4’s current affairs offering”. He further stated that the fact that Stander’s contribution was the lead story “shows how much we [the BBC] valued the piece” [5.8].

Further public awareness of CMS’s statistics research was achieved through *Significance*, a publication of the Royal Statistical Society and the American Statistical Association, the purpose of which is to explain statistical applications to a broad audience. *Significance* is sent to libraries and outreach organizations world-wide, and articles more than a year old are free to download. *Significance*’s Editor Tarran wrote “I’m grateful for the several excellent contributions you [Stander] made to *Significance* throughout 2020, and thank you especially for your rapid response to our call for articles to explain statistical aspects of the Covid-19 pandemic. Our magazine simply could not exist without the contributions of writers like you, who are able to explain difficult concepts in an engaging and informative way. The reach of your writing has been invaluable in helping *Significance* achieve its goal of bringing statistics to a wide, diverse audience” [5.9]. The nine articles written by Dalla Valle, Eales and Stander since 2015 have received over 79,000 views as of November 2020. Stander and Dalla Valle have also published an article in *Communicator* magazine about presenting topical statistics. The print run comprised 1600 copies for members of the Institute of Scientific and Technical Communicators, and for delegates at the Technical Communication UK conference and at “tekomp”, a technical communication event in Germany.

### **Improving pedagogical practices in higher education**

The pedagogical material resulting from [3.2] has enhanced the learning experience at the Massachusetts Institute of Technology, USA. Dr Ellison from the Department of Economics co-taught a course on data analysis for social scientists with Professor Duflo (2019 Nobel Prize in Economics). “We taught it...in 2016 to about 75 students...we assigned an empirical project to the students, and I used [3.2] as an example of a nice data-driven analysis. The students were fascinated to see that statistical techniques that they were learning could be used to analyse historical data such as the longevity of popes and yield interesting insights. I am always looking for new contexts for data analysis to pique the students’ interest, and [3.2] provided one of their favourites” [5.10]. In addition, Craven and Stander co-authored the popular *Advanced Modern Engineering Mathematics* textbook, 5<sup>th</sup> Edition, Pearson, new sections of which are based on research and experience reported in [3.1–3.3, 3.5 & 3.6].

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

5.1 Evaluation of questionnaires filled in by pupils.

5.2 Message from Mrs B Duffield, Subject Leader of Mathematics, Coombe Dean School.

5.3 Plymouth Argyle Football Club (PAFC) Stat-tastic <https://www.pafc.co.uk/news/2019/august/stat-tastic2/>

- 5.4 Top Programme in Sky Bet League One  
2018 <https://www.pafc.co.uk/news/2018/december/top-programme/> <https://www.pafc.co.uk/news/2019/february/top-programme-award>
- 5.5 Best Football Club category of the Football Content Awards  
2020 <https://www.pafc.co.uk/news/2020/june/top-content-team-football-content-awards-2020/>
- 5.6 James Richards, Premier Programme Editor. Testimonial.
- 5.7 Jack's Stats <https://jackleslie.co.uk/jack/> (towards the end)
- 5.8 Ed Davey, BBC journalist. Testimonial.
- 5.9 Brian Tarran, Editor Significance. Testimonial.
- 5.10 Dr Sara Ellison, Senior Lecturer at MIT Economics Department. Testimonial