

Institution: Coventry University		
Unit of Assessment: UOA10		
Title of case study: Maths Meets Myths (MMM)		
Period when the underpinning research was undertaken: From 2010 and ongoing.		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by HEI:
R. Kenna	Professor	from 2002
P. MacCarron	PhD student (now postdoc in Limerick)	2010-2014
T. Platini	Assistant Professor	from 2012
J. Yose	PhD student (now visiting researcher)	2013-2017
Period when the claimed impact occurred: 1 Aug 2013 to 31 December 2020.		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

The impact arises from a long-term project titled “Maths Meets Myths” (MMM). The record-breaking 23,000+ downloads of the pioneering paper [R1] in this REF impact cycle vastly exceeds its 100+ academic citations, reflecting the magnitude, significance and reach of MMM beyond academia. An Altmetrics score of 600+ two weeks after publication of the most recent paper [R5] exceeds that of contemporary research outputs in Nature, Science and PNAS where it was published. Through media coverage [S2], public take-up [S1,S4] and direct industrial changes [S3,S5,S6], MMM culturally informed, influenced and enriched millions and impacted on the products, processes, and policies of industries such as Tata Steel [S7] and on their beneficiaries.

2. Underpinning research

Research on social network structures embedded in ancient and medieval epic narratives started in 2010 with a Leverhulme Trust grant (£85,742) [R1,R2], sparking a new genre of digital humanities that continues today [R5]. In [R1], character-network topologies of British and Irish mythological narratives were compared to those of the Classics, to fiction and to real social networks. Further support from the European Science Foundation (£14,000) and EU Marie Curie Actions (5.3% of €1M awarded for two IRSES grants) continued MMM and a study of Icelandic sagas was performed in [R2]. [R3] addressed Scotland’s famous Ossianic poems. Published in the 1760’s these were claimed to have been translated to English from ancient Scottish-Gaelic sources by James Macpherson. They are among the world’s most important literary works, having ignited the Romantic period in literature and the arts. New network measures developed for [R3] revealed structural affinities with Irish texts whose influence Macpherson disavowed, and a dissonance from the Greek sources which Macpherson sought to emulate. The alignment of this outcome with traditional humanities vindicated the MMM approach [R1-R3].

[R4] provided quantitative elucidation of a 250-year old debate on the nature of conflict in the Viking age in Ireland. The debate had re-entered the public domain around the 1000-year anniversary of the Battle of Clontarf in 2014. The view among the public for centuries was that the battle was the climax of a war where Irish victory finally broke Viking power in Ireland. The revisionist view that the conflict was, instead, between opposing Irish sides was becoming a “new orthodoxy”. [R4] was timed for anniversaries when every parent and school child in Ireland (and many in Scandinavia), and broader public, were engaged in the topic of the debate. The new networks approach delivered a degree of gradation to hitherto rather binary discussions and brought not only the power of mathematical sciences to a vast audience but also enlightened as to the nature of an important historical conflict.

[R5] is the product of a 7-year study funded by Coventry University. It widened the MMM network approach to narratology and was described by PNAS as the “exemplar” for digital humanities. The paper probes how a sprawling, dynamic, complex narrative of massive scale (*A Song of Ice and Fire*) achieved broad accessibility and acclaim without surrendering to the need for reductionist simplifications. It unveils subtle narrational tricks such as how natural social networks are mirrored and how significant events are scheduled.

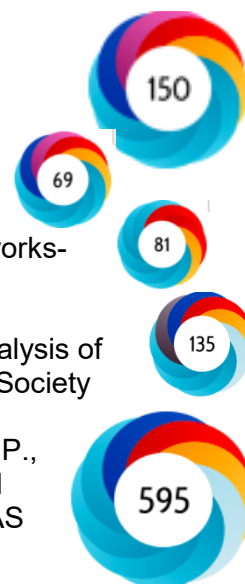
MMM is the basis for three completed PhD’s and a fourth is ongoing – one funded by Leverhulme, one as co-tutelle with the National Academy of Sciences, Ukraine, one to be reciprocated by Tata Steel, and the remainder by Coventry University QR funding. Ten student interns were funded by

Coventry and one by Cambridge University. Impact generated by H2020-funded [R2-R4] between 2013 and 2018 already scored 7/8 for the inaugural Horizon 2020 Impact Awards “to recognise and celebrate outstanding projects that have used their results to provide value for society”. More impact arose from [R3] since 2018 and from [R1] in 2013-2020 and from [R5] in 2020.

3. References to the research

- [R1] Mac Carron, P., & Kenna, R. (2012) ‘Universal properties of mythological networks’. *Europhysics Letters* (9), 28002. DOI:10.1209/0295-5075/99/28002 (over 31,000 downloads and in the top-10 weekly most-read papers every week between 2012 and July 2020)
- [R2] Mac Carron, P., & Kenna, R. (2013) ‘Network analysis of the Íslendinga sögur - the Sagas of Icelanders’. *European Physical Journal B* (86), 407 <https://doi.org/10.1140/epjb/e2013-40583-3>
- [R3] Yose, J., Kenna, R., MacCarron, P., Platini, T. & Tonra, J. (2016) ‘A Networks-Science Investigation into the Epic Poems of Ossian’. *Advances in Complex Systems* (19), 1650008. DOI: 10.1142/S0219525916500089
- [R4] Yose, J., Kenna, R., MacCarron R., & MacCarron, R. (2018) ‘Network Analysis of the Viking Age in Ireland as portrayed in Cogadh Gaedhel re Gallaibh’. *Royal Society Open Science* (5) 171024. DOI: 10.1098/rsos.171024
- [R5] Gessey-Jones, T., Connaughton, C., Dunbar, R., Kenna, R., MacCarron, P., O’Conchobhair, C., & Yose, J. (2020) ‘Narrative structure of A Song of Ice and Fire creates a fictional world with realistic measures of social complexity’. *PNAS* (117) 28582-28588. <https://doi.org/10.1073/pnas.2006465117>

30759 Total downloads



4. Details of the impact

[R1-R5] caught worldwide interest through TV, radio, printed, digital and other media [S2]. Through these, MMM changed understanding and impacted preservation of culture. It started a public campaign [S1], new creative practice, and artistic expression [S1,S3,S4]. MMM changed methods and activities in the private sector [S5,S6] including the steel industry [S7].

E.g., [R3] “sparked ... a debate about cultural misappropriation” [S1c] in Ireland. National media wrote: “When a piece of public art was mooted back in 2018, no one thought it would be controversial” [S1c]. It cost €60,000 and intended to “address the heritage, memory and environment of Athlone” (pop. 21,349) and “in particular the River Shannon” on which it stands [S1f]. However, [R3] identified the selected iconography as representing an “unconscious revival of old colonial attempts to undermine Irish culture and replace it with more civilised art forms. But just as significantly, it also whitewashes an old Irish goddess – Sínann, from where the river gets its name – and replaces it with a classical male god imported into Irish art” [S1c]. Describing “research on cultural misappropriation during the same era as the sculpture” as “a marriage of myth and maths” [S1bc], “what started with a letter turned into dispute that has involved councillors, TDs, Senators and government ministers” [S1b] and “sparked rage among a section of the local community” [S1b]. Tens of millions were informed by international media read by Irish diaspora [S1e]; millions by national broadcast media; tens of thousands by local media; thousands reacted on social media and the blogosphere [S1]. “On 12 July [2019], [Kenna] appeared on Athlone Community Radio to highlight the issue” [S1c]. After explaining [R3] to the public, “an organised opposition group began to form. A Facebook group was established, ... a protest was organised on 5th of August after a meeting with the council” [S1bc]. “An online petition opposing the sculpture was started [by a member of the public (‘FL’) and] attracted over 600 signatures” [S1d]. “A gathering also took place on the town bridge in which people linked hands and called for the proposed sculpture to be replaced with a piece on the theme of Sionnan. The objections to the sculpture were covered in several media outlets including TG4, Midlands103, and thejournal.ie [S1d] whose quiz on the matter reached over 54,069 nationally [S1e]. “On 27 July, an open letter was published addressed to Westmeath County Council. In the letter, signed by over 120 people” [S1c]. ““This is an issue about cultural misappropriation, it’s an issue about replacing a female god with a god from another history, another region’, said FL... who is working on the campaign” [S1c]. ““We shouldn’t have a male god – we have a goddess,’ FL added” [S1c]. “FOI

documentation on the project was issued to OD, who is one of the opponents of the new sculpture” [S1d]. OD “said that the campaign has contacted Minister for Culture [and said] the local TD, had agreed that the symbolism of the statue was an issue” [S1c].



All of these quotes are from independent newspaper items in [S1] which also provide evidence of poetry, art, music, collaborative street performances and community events that reached thousands. Although the colonial male sculpture could not be halted, “the awareness of Sinann is irrevocable and on the ascendancy now” [S1h]. Even politicians have turned: “We have heard a lot about Sionann over the past twelve months and I think it is noteworthy that she is not represented anywhere along the Shannon” said the Mayor in Nov. 2020. He “submitted a Motion [to the] Municipal District on the issue –for “a new art sculpture - namely ‘Sionann on the Shannon’” [S1e]. Thus curiosity-driven mathematics research on an obscure text reignited awareness of a mythological figure whose very purpose is to promote curiosity [S1g].

While media was central to the above impact from [R3], MMM impact on and via media is far wider. The cumulative Altmetrics score of over 1,000 for [R1-6] exceeds counterpart scores for REF2014 UOA10 impact case studies [https://impact.ref.ac.uk/casestudies/]. But the reach and significance of the impact also goes far beyond the online impact captured by Altmetrics. Additional impact is evidenced through broadcasting data and independent citations in the media over the entire REF period [S2]. Examples include a 4-minute interview about [R5] on *Digital Planet*. “This radio show is broadcast on *BBC World Service* to a reach of 370m, has 110-140k weekly downloads and is one of the most popular BBC podcasts. There is also an active Facebook group ‘*Digital Planet Listeners*’ with 10k followers” [S2a]. With 423,000 listeners “*Morning Ireland* is the breakfast news programme broadcast by *RTE Radio 1*” – “Ireland’s most listened to radio programme” [S2a]. An interview about [R4] lasted 5 minutes 39 seconds. *RTE1 TV* is “the most popular and most watched television channel in Ireland” and a 2.20-minute interview programme on the *Six O’Clock News* had an audience of 866,000 (53.4% of the available Irish audience) [S2a]. This was repeated on the 9-o’clock news and online with similar reach. Other broadcasts included on *Deutschlandradio*, *ORF*, *BBC*, and other radio stations internationally [S2a].

Impact via printed media (also not captured by Altmetrics) included repeated coverage (>3 items) in the *Irish Post* [S1f] whose UK readership is 80,000 and whose international reach is 3 Million visitors online every month and 50 million on Facebook [S2]. Repeated coverage (3 items: 1300, 400 and 500 words) in *The Times* reached 446k people [S2b]. Similar impacts in the UK include through (assuming a readership-per-copy ratio of approx. 2.5) the *Independent* (564k), *Daily Express* (979k), *Daily Mail* (4m, twice) and *Scotsman* (97k). In Ireland the *Irish Times* (286k readers) impacted at least twice, as did the *Irish News* (80k) and *Irish Examiner* (236k). The *Anglo Celt* (33k) and the *Westmeath Independent* (34k) are examples of local media (the latter ran dozens of items impacted by the research [S1,2]). The Nordic countries were especially interested in [R2] with *Morgunbladid* (55k), *Ingenioren* (287k), *Nordic Page* (8k) representing Iceland, Denmark, Norway respectively and *Finbay* (15k) bringing it to Finland. [R5] impacted strongly in Austria and Switzerland through *Wiener Zeitung* (100k), *Aargauer Zeitung* (298k), *Südostschweiz* (313k), *Toggenburg* (46k). *Frankfurter Allgemeine* (383k), *Neues Deutschland* (49k) and *Blick* (215k) impacted the work on Germany as did *Sud Ouest* (354k) in France, *Magyar Nemzet* (64k) in Hungary, the USA, Russia, India and Pakistan through *News Break* (45m), *Daily News* (1.29m), *Pravda* (100k), *Times of India* (7.2m), *The Statesman* (500k), *Business Standard* (542), *Daily Times* and other outlets. These examples are representative only; many more are detailed in [S2]. Popular science magazines ran still longer reports [S2d]. Reader numbers are not always available, but Facebook followers are indicative. Examples include a 2,000-word interview on MMM in *Undark* magazine (216,000 followers), a 680-word item in *Nautilus* (145,300), and a

Impact case study (REF3)

2,300-word interview in *The Verge* (536,000). The interview gained over 1,000 *Facebook* likes in under a week and triggered over 500 tweets. Others include *Sciences et Avenir* (2 million followers), *Descopera* (a Romanian popular science magazine with 378k followers) and *Phys.Org* (1.4m) who reported on [R2] [R4] and [R5] in 2014, 2016, 2018 and 2020. The last of these was a 764-word item shared over 300 times on *Facebook* while the 2018 item was shared 457 times. *Science* magazine (620 words), *Science Daily* (756 words), *Live Science* (821 word) and many more brought the work to millions interested in science. Again, these examples are indicative of impact not picked up by Altmetrics and [S2] elaborates.

Even longer reports impacted teachers, learners, and the industrial user community. A 6-page (4,079-word) feature about [R2] in *Significance* (magazine of the *Royal and American Statistical Societies*, with bimonthly circulation 28,000 and supplemented online, and on *Facebook*, *Twitter*, etc.) was the front-page feature [S2d]. Likewise, a six-page feature on [R3] was the front-cover for *Physics World* (from the *Institute of Physics* with 110,000 monthly readers plus online) [S2d]. *Siam News* (official news journal of the *Society for Industrial and Applied Mathematics* with 13,000 members) posted a video [S3d]. There are multiple evidences of indirect impact. E.g., an earlier 1,179-word item in SIAM news impacted Donald Knuth ("Father of Algorithms") to send a congratulatory letter which, posted on Facebook, impacted 2.4k interested public [S2g]. These and many more impacts are documented and evidenced by broadcasting data, download figures, media citation, etc. in [S2] which are by no means complete.

Corporate and industrial impacts are also multifold. Following [R2] and associated media coverage, Executive Publishing Editor at *Springer Nature* stated he "would be truly enchanted to do [a] mouthwatering" book on MMM as "an exciting collaboration." Through this arose *Springer* monograph *Maths Meets Myths: Quantitative Approaches to Ancient Narratives* [S5]. *Springer* testify the "research is of great importance and benefit to Springer Nature" and reviews (including on *Amazon*) have been viewed over 200 times [S5]. The extent to which 10,000 downloads exceed academic citations evidences non-academic impact as do hundreds of hard-copy sales [S5]. On completion of the book (2017) then Senior Editor testified it is "a very inspiring publication for the Springer Physics Editorial team" which helped "opened up a whole new realm of publications in journals and books". Indeed, Springer also testify that "The book was an inspiration for a new Series, "Simulating the Past" with Kenna as Series Editor" [S5]. Besides generating positive impact like this, negative impact on Editors and the public was halted. Having discussed [R1-4] with Kenna, in 2018 *New Scientist's* Feature Editor sought advice on what turned out to be flawed research by other researchers. His statement "Your feedback convinced my editors not to run a short news piece on the work" illustrates how MMM saved *New Scientist* from an embarrassing mistake [S2e]. Diversity is also evidenced by impact on the award-winning LAS Theatre [S3e]. Awareness of MMM having been ignited through media coverage of [R1], the team was invited to do six 20-minute shows over three days in 2014 for the Mysteries Festival in Coventry about the evolution of ideas and creativity. Approximately 100 people attended each event. Independent corroborative evidence is provided in [S3e]. Further artistic impact included on *Sundog Industries*, producers of animation and motion graphics [S3d]. In 2014 MMM motivated them to develop a video (in their own time, at their own expense) describing [R1] and its success inspired establishment of *Sundog Industries* itself. The video is since used to advertise the quality of their work. A second video based on [R3] impacted SIAM news. It also inspired discussion and debate on YouTube and elsewhere – see [S3] for a testimonial, quantitative indicators, and independent evidence of debate. Two further videos representing [R3] and [R5] and produced independently out of sheer interest are documented in [S3]. Diversity beyond the artistic is evidenced too; [R1] ignited "interested in character networks" by Wolfram Solutions, a consulting service of Wolfram Research. Finding [R4] "fascinating" their Project Director "wanted to reproduce [MMM results] with [their] own code for future use" [S6]. Wolfson downloaded [R4]'s "truly remarkable dataset" to "delve into them, examining their breadth and depth." They replicated [R4] using Wolfram's Mathematica software. After six years of sustained impact following [R1], and two years of direct engagement following [R4], the Director suggested "student interest in this kind of text analytics". The collaboration with Tata described next funded the suggested MMM student. Emails are available in [S6] to verify the above impact alongside a testimonial on behalf of the Project Director of Wolfram Solutions.

Impact case study (REF3)

Steel production involves multiple units of product information in multiple processes across multiple locations. Prior to the impact of [R3], the bulk of project time in Tata Steel's Data Science and Analytics R&D Department was spent data harvesting and collating rather than analysing data for quality control and efficiency measures. MMM research directly impacted on Tata Steel through-process tracking activities across the full lineage of product development. [R1-4] had developed sentimental analysis for researching networks embedded in texts and priority ranking measurements from previous pioneering research into network resilience. The connection between text analysis and through-process tracking was made by Tata themselves when they came across [R3]. Importing the methods, Tata Steel developed guides to improve tracking capability. The ratio of time spent on data harvesting to that spent on analytics was approximately 80:20 prior to the impact of MMM. As data collection sped up, the 80:20 rule was reversed, allowing experts more time spend analysing the data. Tata estimate the cost savings from impact in person-hours alone approximate to £80,000 annually. But the impact is more than this; in 2019 Tata Steel changed a major part of Data Science and Analytics R&D road map and added Coventry University to their trusted partners for external collaborations. Tata Steel also replicated a visualization method developed for mythological networks in [R3] to develop an interactive user interface for digital-passport display purposes involving product information and lineage. Such was the impact of [R3] that two MMM PhD students (one of whom worked on [R3,R4,R5]) were awarded key positions (not furloughed during Covid) in Tata's Data Science and Analytics R&D team. A third student started in Coventry in 2019 and is co-supervised by Tata Steel's Data Science team. Together they integrated Natural Language Processing to the above mentioned sentimental and resilience analyses. Additionally, they created a co-authorship network which displays Tata Steel researchers and their internal collaborators, and a second network has also been created for the journal papers that share common themes. In August 2020 the MMM team presented to senior Tata staff. Individual Business Units in Tata Steel now focus on root cause analyses and identify individual problems in efficient and cost-effective manners. The direct impact of [R1-4] for optimization algorithms saves Tata [Text removed for publication] annually but the full indirect impact is unquantifiable. See source [S7] for a testimonial.

Impact continues; on 10.11.2020, the Irish Post (with a reach of millions), Rathcroghan Visitor Centre and Story Archaeologists teamed with MMM to run an arts competition (£4,000) [S1f,g]. Public awareness was retained with eight weekly features to 31.12.2020 and beyond. Together with Tata Steel and other partners, they invoke more river goddesses to impact the mathematics generated by the Fluid and Complex Systems Research Centre onto an inspired world.

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

S1, S2 and S3 are long documents containing multiple corroborative sources, many of which could have been entered here as a single item. S4, S5 and S6 contains single sources as examples.

[S1] S1=Sinann.pdf. This documents multiple sources to corroborate impact pertaining to the river goddess including independent reports (a,b,c,d) quoted above, more newspaper reports, online activities, the petition, open letter, FOI documentation, etc. (e); Irish Post (f); Story Archaeology (g); independent quotes (h) and a timeline to help understand the depth and endurance of the impact (i).

[S2]: S2=Media.pdf. This documents sources to corroborate impact on and via TV & radio (a); printed newspapers (b); magazines (c); magazines read by public interested in science (d); online newspapers (e); online science media (f); and earlier impact (g).

[S3]: S3=Videos.pdf. Video by Screen Rant (a); podcast by Estradiol Illusions (b); event by Data Beers (c); videos and testimonial by Sundog Industries (d); Institute of Impossibility theatre performance (e).

[S4] S4=Athlone.pdf. This document contains evidence of perception changes pertaining to the usage of statistical physics to identify misappropriation of mythology. It supplements [S1] above.

[S5] S5=Springer.pdf This document contains an example of evidence of impact on publishers. This example supplements [S2] where far more impact is documented.

[S6] S6=Wolfram.pdf. This document gives a single example of how MMM impacted on the NLP user community. Further evidence is contained in [S3].

[S7] S7=TataSteel.pdf. This documents impact on Tata Steel.