Institution: University of Leicester

Unit of Assessment: 7 Earth Systems and Environmental Sciences

Title of case study: 'Flying Monsters 3D': extinct flying reptiles star in an award-winning multi-media offer promoting science on a global scale.

1. Summary of the impact

Research by David Unwin on extinct flying reptiles underpinned a successful bid to produce a 3D digital product backed by funding, principally from Sky, of more than three million pounds. This facilitated development of 3D film technology by the British film industry and resulted in a BAFTA award winning digital film 'Flying Monsters 3D'. FM3D was hosted by David Attenborough, featured Unwin and was delivered via television, cinemas and the web. The film, which has generated revenues of more than $10 million, is primarily targeted at children and has helped foster positive attitudes toward natural history, the sciences and academic research.

2. Underpinning research

Pterosaurs, the first back-boned animals to achieve true flapping flight, were a key component of Mesozoic faunas and dominated the skies for more than 140 million years. This iconic group, without which no dinosaur diorama, film, or documentary would be complete, were unique in many respects, not least the giant sizes achieved by some species with wingspans in excess of 10 metres. The sheer exoticism of pterosaurs coupled with their patchy fossil record has rendered these creatures one of the great enigmas of palaeontology and, until recently, a mass of contradictions, debates and controversies. During the last two decades, a series of important new finds coupled with the application of modern approaches such as scanning electron microscopy and phylogenetic analysis have revolutionised our understanding of the biology and evolutionary history of pterosaurs.

David Unwin, based in Leicester since 2006 and Reader in Palaeobiology since 2009, has been at the forefront of this research, authoring more than 100 presentations, 60 papers, a book and several edited volumes on pterosaurs. Research projects founded and directed by Unwin, many of them involving international collaboration (e.g. in Argentina, China, Germany, Romania, Russia, Mongolia, Spain, and the USA) have played a pivotal role in shaping our understanding of these unique animals and helped solve a string of outstanding questions concerning pterosaur anatomy, locomotory abilities, reproduction, physiology, taxonomy and evolutionary relationships.

Recently completed projects led by Unwin (**1**-**6**) directly contributed to several key episodes of 'Flying Monsters' and underpinned the general historical narrative of the film. Unwin's phylogenetic analyses of pterosaurs, the most comprehensive in the field, played a critical role in identifying a series of new forms (*Shenzhoupterus* (**2**), *Darwinopterus* (**1**), *Alanqa* (**5**)) and established their relationships to other pterosaurs. *Darwinopterus*, heavily featured in the film, is one of the most important fossil finds ever made. This pterosaur, first recognised by Unwin in Beijing in 2009, has a highly unusual anatomy, consisting of a remarkably advanced skull and neck perched on a primitive body. *Darwinopterus* thus fills a large and seemingly unbridgeable evolutionary gap between primitive and advanced pterosaurs. As Unwin and colleagues have shown (**1**), this pattern points to a 'modular' form of evolution that could explain a long-standing problem: the frequent appearance, in the fossil record, of relatively rapid, large-scale evolutionary changes.

Unwin's research on the reproductive biology of pterosaurs (**3**,**4**), in collaboration with colleagues in the UK and China, led to startling new insights into the nesting behaviour of these animals: they buried their eggs, like many reptiles, rather than sitting on them as birds do. An extraordinary specimen of a female *Darwinopterus* preserved in association with an egg, dubbed 'Mrs T' by Unwin, further emphasised the remarkably reptilian nature of pterosaurs (**3**). Studies on exceptionally well preserved skeletons by Unwin and colleagues based in the USA resolved a particularly troublesome paradox: how was the respiratory system of the reptile-like pterosaurs able to support the highly demanding activity of flapping flight (**6**). This work also supplied fresh insights into the evolution of giant size in pterosaurs which was facilitated through the extensive hollowing out of bones and soft tissues by extensions of the lungs

3. References to the research

1. Lü Junchang, **Unwin, D. M.** & Jin Xingsheng. 2010. Modular evolution in a long-tailed pterosaur with a pterodactyloid skull. *Proceedings of the Royal Society B: Biological Sciences*, **277**, 383-389.
2. Lü, Junchang, **Unwin, D. M.**, Xu Li & Zhang Xingliao. 2008. A new azhdarchoid pterosaur from the Lower Cretaceous of China and its implications for pterosaur phylogeny and evolution. *Naturwissenschaften*, **95**, 891-897.
3. Lü Junchang, **Unwin, D. M.**, Deeming, D. C., Jin Xingsheng, Liu Yongqing and Ji Qiang. An egg-adult association, gender, and reproduction in pterosaurs. *Science*, **331**, 321-324.
4. **Unwin, D. M.** & Deeming, D. C. 2008. Pterosaur eggshell structure and its implications for pterosaur reproductive biology. *Zitteliana*, **28**, 199-207.
5. Ibrahim, N., **Unwin D. M**., Martill, D. M., Baidder L. & Zouhri, S. 2010. A new pterosaur (Pterodactyloidea: Azhdarchidae) from the Upper Cretaceous of Morocco. *PLoS ONE*, **5**(5): e10875. doi:10.1371/journal.pone.0010875.
6. Claessens, L. P. A. M, O'Connor, P. M. and **Unwin, D. M.** Respiratory evolution facilitated the origin of pterosaur flight and aerial gigantism. *PLoS ONE*, **4**(2): e4497, doi:10.1371/journal.pone.0004497.

Royal Society International Joint Project Grant: 'Reproduction and early ontogeny in pterosaurs'. Unwin and Lü (Chinese Academy of Geological Sciences, Beijing, China), 2010-12; £11,800.

References 1-3 and 5-6 appeared in well known, highly ranked international science journals. Journal impact factor, number of citations and, in the case of PloS ONE, number of views, are as follows: (1.) 5.68, 39; (2.) 2.14, 29; (3.) 31.03, 22; (4.) 0.17, 3; (5.) 3.73, 16, 15,317; (6.) 3.73, 35, 22,861.

4. Details of the impact

A. Contributions to the film:

I. A physical role in the film. Unwin featured in two stories, '*Darwinopterus*' and 'Robodactylus', filmed in London at the end of July 2010. With the exception of the host, Attenborough, this was the longest appearance in the film by a contributor. Unwin also appeared in the '*Making of Flying Monsters*' (**A**).

II. Unwin was the lead scientific consultant on the film and contributed to the development of the script, assessment of ideas and story lines and fact-checking. He also provided critical feedback on animations and film sequences. Discussion of the central narrative and of several episodes, e.g. on *Darwinopterus*, took place during an all-day meeting in London in early 2010 and subsequently by email and phone (**B**).

III. Generation and provision, between December 2009 and April 2010, of information on film locations (e.g. Solnhofen, Germany; Crayssac, France), an extensive list of contacts and advice on the suitability and accessibility of specific objects (e.g. specimens of *Darwinopterus*) (**B**).

B. Investment in the British Film Industry.

Approval of the film project by Sky brought considerable benefit to Atlantic, the producer of FM3D, and its subcontractors (**C**). Principal among these were: ONSIGHT 3D, responsible for postproduction and editing services; Vision3 who supervised the 3D filming and provided production support; ZOO , who generated the high resolution CGI suitable for the very large screens found in Imax theatres; and FIDO, who developed and built models used in filming and CGI production (**C**). In total, more than 130 people were involved in the project which spanned the period late 2009 to late 2010 (**D**).

The primary benefit came in the form of financial funding (>£3 million) principally from Sky. Work on FM3D provided Atlantic and its subcontractors with a unique opportunity to develop high end 3D film technology and processes, described by Atlantic CEO Anthony Geffen as 'an evolving tool-set' (**E**), and thus acquire expertise and experience in this important and rapidly developing area. 'Flying Monsters' thus became a 'showcase for 3D moviemaking' as applied to documentaries (**F**). Building directly on the financial and critical success of this project (see below) Atlantic have gone on to produce a series of documentaries (e.g. 'Galapagos 3D', 'Micro Monsters 3D'), that have also met with critical acclaim (**F**).

C. Revenue generation and distribution

Unusually, for a science documentary, FM3D has been a great financial success. By May 2013 it had generated more than ten million dollars in revenue from Imax and other movie theatre ticket sales and this will rise further as the film continues to be shown worldwide (**G**).

A unique, ground-breaking feature of FM3D, vastly increasing its potential audience, has been its delivery across an array of platforms. Through collaboration with National Geographic the film has been distributed to film theatres across the globe (**G**). The film can also be streamed from the internet, is available on DVD and Blue Ray DVD, was broadcast on terrestrial television (with a debut on Xmas Day 2010) and content can also be viewed via an app for the iPad and Android (**G**).

The total viewing audience exceeds one million. The film also has a very large geographic footprint, having been shown in more than 75 IMax theatres worldwide distributed across 20 countries (**G**).

D. Evaluation of 'Flying Monsters 3D'.

To date FM3D has been awarded five prizes (**H**). The most prestigious of these, a BAFTA for the best specialist factual film, was awarded in 2011. The film also won a Special Award given by the International Broadcasting Convention, for best science film, in 2011, best Earth and Environmental Program at the Jackson Hole Wildlife Film Festival in 2012, and a Panda Award for best 3D film at Wildscreen 2012.

The film has garnered a large number of positive reviews. Mean aggregations of these posted on the principal film review websites show consistently high scores (e.g. Rotten Tomatoes = 100%; IMDb = 7.0/10 for 279 reviews (**I**)).

E. Target audience and educational impact.

The principal target of this film was children of school age. Many film reviews comment positively in this respect ("the majority of the 3D imagery is impressive enough to instill a sense of awe among its predominantly school-age target audience", *Timeout* 03/05/11) showing that this aim was achieved (**I**). Audience figures indicate that more than five hundred thousand school-age children have already seen FM3D (**G**). The positive educational impact of the film is further demonstrated by National Geographic which has used their web-site to deliver additional educational content, based on FM3D and aimed at school-children (**J**). Six hours of teaching material introduces children to aspects of palaeontology and to broader concepts such as biomechanics and evolution (**J**). Principal natural history museums, such as the AMNH, New York, have also been incorporating FM3D into their educational programmes (**J**).

5. Sources to corroborate the impact

A. Details of 'Flying Monsters 3D': www.flyingmonsters3dmovie.com.
http://movies.nationalgeographic.co.uk/movies/flying-monsters.
Details of 'The Making of Flying Monsters 3D': www.atlanticproductions.tv/productions/making-

david-attenboroughs-flying-monsters.

B. Meeting agenda for Flying Monsters 3D, March 2010 and emails between DU and Atlantic, 12/11/2009 to 17/11/2010

C. Principal companies involved in the production of 'Flying Monsters 3D': Atlantic: www.atlanticproductions.tv; ONSIGHT 3D: www.onsight.co.uk; Vision3: www.vision3.tv; ZOO: http://zoovfx.com; FIDO: http://fido.se/work

D. Cast list for 'Flying Monsters 3D': www.imdb.com/title/tt1777610/fullcredits.

E. Kaufman, D. 2012. 'Behind the lens: Flying Monsters 3D', http://library.creativecow.net/kaufman_debra/Flying-Monsters-3D/1.

F. Details of Atlantic films:
'The Bachelor King 3D': www.atlanticproductions.tv/productions/the-bachelor-king-3d-with-david-attenborough/
'Kingdom of Plants 3D': www.atlanticproductions.tv/productions/kingdom-of-plants-3d-with-david-attenborough.
'Galapagos 3D': www.atlanticproductions.tv/productions/galapagos-3d.
'Micro Monsters 3D': www.atlanticproductions.tv/productions/micro-monsters/
News stories and links to reviews of these films: www.atlanticproductions.tv/news.

G. Revenue generated by 'Flying Monsters 3D':
http://press.nationalgeographic.com/2013/05/08/flying-monsters-10-million-box-office-revenue/
See also: http://www.boxofficemojo.com/movies/?id=flyingmonsters.htm.
Distribution: National Geographic: http://movies.nationalgeographic.co.uk/movies/flying-monsters/theater-listings/
Video on demand (download from internet): http://download.cnet.com/Flying-Monsters-3D/3000-31711_4-75352175.html.
DVD: http://www.atlanticproductions.tv/productions/flying-monsters-3d.
Blue Ray: www.blu-ray.com/movies/Flying-Monsters-3D-Blu-ray/42028/#Review.
TV: http://www.atlanticproductions.tv/productions/flying-monsters-3d.
Phone app: www.amediatek.com/project/flying-monsters-3d/.

H. Prizes for 'Flying Monsters 3D':
British Academy of Film & Television Arts (BAFTA) for Best 3D Film 2011:
http://www.bafta.org/television/awards/winners-2011,2394,BA.html#jump9.
See also: www2.le.ac.uk/news/blog/2011-archive/may/bafta-win-for-3d-flying-monsters-film.
Special Award for Innovation at the International Broadcasting Convention in Amsterdam 2011:
http://www.ibc.org/page.cfm/link=467
Best Science Film from The Association of International Broadcasters 2011:
http://theaibs.tv/2011-aibs-award-winners.
Panda Award for 3D Film at Wildscreen 2012:
www.wildscreenfestival.org/index.php?pageid=426&parentid=368.
Best Earth and Environmental Science film at the Jackson Hole Science Media Awards 2012:
www.jhfestival.org/sciencemedia/winners.htm
Further details of awards and prizes can be found in the 2012 version of 'Press Kit for Flying Monsters' available from Atlantic (tanyaw@atlanticproductions.co.uk)

I. Film reviews of 'Flying Monsters 3D':
www.flyingmonsters3dmovie.com/media-coverage/#3-awards-coverage.
Rotten Tomatoes: http://www.rottentomatoes.com/m/flying_monsters_3d_with_david_attenborough/
IMDb: http://www.imdb.com/title/tt1777610/?ref_=ttfc_fc_tt.
Timeout: http://www.timeout.com/london/film/flying-monsters-3d.

J. National Geographic education site:
http://education.nationalgeographic.com/education/flying-monsters-education-outreach/?ar_a=1&ar_r=1
See also the American Museum of Natural History 'Learn and Teach' website:
http://www.amnh.org/learn-teach/grades-3-5/adventures-in-science/take-to-the-skies-with-pterosaurs-grades-3-4-5.