Journal of Natural Science Collections

Title: Using theatre skills in a science exhibition: Dinosaurs of China in Nottingham

Author(s): Nunn, M. & Smith, A.S.

Source: Nunn, M. & Smith, A.S. (2018). Using theatre skills in a science exhibition: Dinosaurs of China in Nottingham. *Journal of Natural Science Collections*, *Volume 6*, 99 - 111.

URL: http://www.natsca.org/article/2516

Using theatre skills in a science exhibition: Dinosaurs of China in Nottingham

Martin Nunn* and Adam S. Smith

Address: Nottingham City Museums and Galleries, Nottingham, UK

**Corresponding author: martin.sciencegeek@gmail.com*

Received: 16/07/2018

Accepted: 02/10/2018

Citation: Nunn, M. and Smith, A.S., 2018. Using theatre skills in a science exhibition: Dinosaurs of China in Nottingham. *Journal of Natural Science Collections,* 6, pp.99-111.

Abstract

Dinosaurs of China was a world-exclusive temporary exhibition of iconic, mostly feathered dinosaur fossils, which have revolutionised our understanding of dinosaur appearance and biology over the last 20 years. Hunter the *Sinraptor* was a puppeteer-operated semi-animatronic theropod dinosaur costume. Hunter, accompanied by Dinosaur Rangers, publicised the exhibition within Nottingham and beyond, visited schools to explore dinosaur ecology, and interacted with visitors to the exhibition. The process of putting this element of the exhibition into place included procurement of the costume, 'Dino-Factor' auditions to find a skilled puppeteer, and recruitment of volunteer Rangers. Hunter and the Rangers contributed towards exhibition marketing and the public learning experience. There is an extensive body of literature on the value of integrating dramatic arts into schools and museums, and our findings add to this body of evidence. Hunter inspired engagement with science in formal and informal settings. However, the dinosaur had mixed impacts on visitor expectations, with some anticipating animatronics to feature within the exhibition itself. In conclusion, we show that if used with care, theatre and performance skills can boost marketing and enhance scientifically rigorous learning experiences.

Keywords: dinosaurs, puppets, theatre, drama, China, animatronic, Nottingham, science education

Introduction

From July to October 2017, Nottingham City Museums and Galleries (NCMG) hosted an exhibition of iconic dinosaurs and Mesozoic birds from China. The specimens on display spanned from the Early Jurassic to Late Cretaceous, and told a story of our changing understanding of dinosaurs and their relationship to living birds (Smith and Qi, 2017; Smith and Qi, in prep.). On display were dinosaur species known from the early expeditions of Roy Chapman Andrews (Granger and Gregory, 1923; Osborn, 1924; Andrews, 1932), species discovered during the early days of Chinese palaeontology by C.C. Young (Sekiya and Dong, 2010; Young and Zhao, 1972), and stunning recent discoveries of feathered dinosaurs (Chen, Dong, and Zhen,1998; Xu, Wang, and Wu, 1999; Xu , Zhou, and Prum, 2001; Xu et al., 2003; Xu and Norell, 2004; Xu et al., 2007; Xu et al., 2015; Zhang et al., 2008).The latter have radically changed our understanding of dinosaur appearance and biology over the past 20 years (Benton et al., 2008; Zhou,

Barrett and Hilton, 2003; Zhou, 2006; Zhou and Wang, 2010; Zhou, 2014; Pan et al., 2013; Zhang et al., 2010; Smithwick et al., 2017).

Two key messages of the exhibition were: (a) many dinosaurs were feathered, and (b) the dinosaur origin of birds (Chiappe, 2004; Zhou, 2004; Hone, 2010; Chatterjee and Templin, 2012; Smith and Qi, 2017). Consequently, many of the fossils in the exhibition were feathered dinosaurs, including holotypes (e.g. real fossils of *Microraptorgui* Xu et al., 2003 and *Caudipteryx dongi* Xu and Wang, 2000) and other scientifically significant specimens (e.g. *Sinosauropteryx prima* Ji and Ji, 1996; *Yanornis martini* Zhou and Zhang, 2001; *Confuciusornis sanctus* Hou et al., 1995).

As part of the planning for the Dinosaurs of China exhibition, NCMG decided to purchase an animatronic dinosaur puppet as a promotional tool. This 'animal' became known as Hunter (Figure 1). Once in operation, it became clear that as well as being an excellent marketing tool, Hunter possessed considerable potential as an educational resource.

Figure 1. Hunter outside Wollaton Hall. (image NCC 2017)

The efficacy of the dramatic arts in science education

There is an extensive literature on the impact of drama-related activities and theatrical performances on science literacy in school and museum environments. Many of these are anecdotal and non-qualitative regarding the efficacy of the techniques used, yet all point towards positive outcomes and benefits to the approach. A number of authors (Bicknell and Fischer, 1994; Baum and Hughes, 2001; OkurBerberoglu et al., 2014) have attempted to provide qualitative and/or quantitative evidence, and they all show a strong positive impact for theatre programmes.

Classroom environments

According to Dorion (2009), there is a long history of using cross-curricular drama activities in education, possibly dating back over 300 years, but such approaches have only been applied to science education since the 1980s. One of the earliest exponents was Cornell (1979; 1989) who popularised the use of play in environmental education. Since then, many approaches and artistic forms have been used within the classroom environment, such as shadow puppets (Tselfes and Paroussi, 2009), role-play (McSharry and Jones, 2000), magic and role-play (Papalaskari et al., 2006), along with traditional theatre plays (Odegaard, 2003; Dorion, 2009). These studies all agree that theatre is an effective way to engage children of various ages with science, but there is little evidence to support the development of factual knowledge through these techniques. Overviews of a range of techniques broadly support this view (Bruner, 1992; Mesure, 2005; Kind and Kind 2007). These works agree that there is a need for high quality quantitative studies to support anecdotal reports of efficacy.

Out of classroom environments

The situation for out of classroom environments is similar. A Centre For Advancement of Informal Science Education (CAISE) report (McCallie et al., 2009), and work by Ledgard (2008) and Peleg and Baram-Tsabari (2011), all agree that people can learn through theatre and become emotionally engaged. Peleg and Baram-Tsabari (2011) stressed the importance of theatre for early exposure to scientific ideas and principles with primary school children. Ledgard (2008) focused on the usefulness of these techniques for tackling social and societal issues, especially with potentially contentious questions, where it can act as a springboard for debate. McCallie et al. (2009) recognised the value of drama as one of many tools that informal science education facilities can use for public engagement with, and understanding of, science. They also noted that the dramatic arts can play a role in building a more scientifically literate society with a population better able to contribute towards reasonable decision making. Chemi and Kastberg (2015) evaluated different approaches and demonstrated that, in general, performances that actively engage the audience into becoming a part of the performance are the most effective. This is something that we attempted to achieve with Hunter. Again, the majority of literature examined on this matter agrees that further research is needed.

Museums

The picture within the museum environment is somewhat more robust. There is a longer history of using theatre-inspired interpretation activities to support museum learning (Alsford and Parry, 1991). The origins of this approach appear to be linked closely with living history and outdoor sites, with a slower uptake amongst indoor museums (ibid). Museums need a slightly different approach to more formal educational establishments, as they are destinations for leisure as well as educational outings. Consequently, both the educational and entertainment value of performances needs to be high (ibid). Due to this long history, there are a number of studies that have produced quantitative evidence for the efficacy of this approach. Bicknell and Fisher (1994) found that most visitors - and especially children - enjoy these shows, and this results in an increased engagement with the museum environment. Further, they state that performances are a "...success in communicating information, complexity, content and clarify detail..." (Bicknell and Fisher, 1994: p.86). Similarly, Baum and Hughes (2001) found drama approaches to be good for exploring complex ideas, developing emotional connections, and often led to deeper, more nuanced thoughts on a topic. OkurBerberoglu et al. (2014) conducted a statistical analysis on the effectiveness of a theatre performance compared to a lecture, and found that audiences who watched the theatre show had better retention of knowledge than those who attended the lecture.

School field trips

There are also a number of evaluations of school field trips. Behrendt and Franklin (2014) noted that "experiential learning at formal and informal field trip venues increases students interest, knowledge and motivation" (ibid: p.235), but went on to note that the teacher's role in planning implementation and reflection after the visit are essential for a worthwhile field trip. Whitesell (2016) analysed the impact of field trips on long-term knowledge retention and performance in standardised science test scores. The statistical analysis found a small positive impact for disadvantaged children, which may be down to them getting limited educational enrichment opportunities outside of the school environment.

Other examples

We can also look beyond academic literature to see impacts of drama on science learning. The eminent physicist Stephen Hawking co-authored an excellent children's adventure novel to communicate cosmological ideas to a young audience (Hawking and Hawking, 2008). Children's book author Jonathan Emmett has produced a wonderful introduction to the process of evolution for preschool and 'early years' children (Emmett, 2018). Palaeontologist Steve Brusatte has credited the original *Jurassic Park* movie with inspiring an interest in palaeontology: "So many of my colleagues, people of my age, my generation, would tell you point-blank that *Jurassic Park* made them want to be a scientist, and it's true that a lot of museums and a lot of universities started to hire palaeontologists right after that film, because dinosaurs exploded." (Anthony, 2018). The value of literature and film for exploring science has also been espoused by Klein (2006).

Consequently, there is strong justification for the use of a dinosaur puppet in an appropriately considered theatrical performance as a mechanism for enlightening people of all ages on the wonders of the Mesozoic world.

Design and Purchase

The first stage in realising the vision to have a dinosaur mascot for the exhibition was to acquire a puppet or costume. A number of companies in China manufacture these types of puppets as off-the-peg items. NCMG wanted a puppet that would represent one of the dinosaur skeletons in the exhibition, and a feathered dinosaur puppet would have been ideal for pre-empting and reinforcing key messages from the exhibition. From a marketing perspective, something large and eye catching was desirous. To be functional and realistic-looking, choices were limited to large bipedal dinosaurs, allowing an operator to climb inside the costume. Unfortunately, most feathered dinosaurs are small (under a metre long in most cases), and no convincing feathered dinosaur puppets were available.

Due to these constraints, the choice was narrowed down to the large, non-feathered, predatory theropod *Sinraptor*, from the Jurassic (Currie and Zhao,1993). A seven-metre-long sub-adult skeleton of *Sinraptor dongi* Currie and Zhao, 1993 was a star attraction in the exhibition (Figure 2). A small (i.e. juvenile) *Sinraptor* puppet was selected as the most appropriate mascot to represent the exhibition.

Figure 2. Sinraptor dongi *replica skeleton in the Great Hall. (image NCC 2017)*

A *Sinraptor* puppet was also relatively cost-effective to manufacture. At the request of the exhibition curator (author AS), Chinese company Ocean Arts were able to make bespoke modifications to one of their off-the-peg *Tyrannosaurus rex* Osborn, 1905 puppets. These modifications included a larger and longer *Sinraptor*-like arm, a three-fingered hand, and a custom paint finish. The result was a unique 3.5-metre-long stylised representation of a juvenile *Sinraptor*.

Recruitment and character development

A puppeteer was selected via an audition process that we called 'Dino-Factor' in a parody of the well-known television talent show X-Factor. This was judged by a panel of people from the Dinosaurs of China Project Executive Group, and also included a Simon Cowell (a member of the X-Factor panel) lookalike (Figure 3a). The panel were looking for people possessing the physical ability and skills to bring the puppet to 'life' in the eyes of an audience. This genuine recruitment process was also a part of the overall pre-publicity and marketing strategy, and generated a lot of interest from local media (ITV, 2017; Johns, 2017). It also allowed NCMG to recruit a highly skilled puppet operator, Izzy Hollis (Figure 3b), who gave Hunter his own individual character and behavioural quirks, which were key to making him come to life in the eyes of the audience.

The character of Hunter that developed was predominantly that of a mischievous puppy, for a number of reasons. Firstly, some young children found the costume frightening, so it was important to make Hunter friendly while still a bit edgy and naughty. Secondly, at a little over three metres long, Hunter was considerably smaller than an adult *Sinraptor*. Ascribing an actual numerical age to Hunter was difficult (see 'Educational appearances' below), but a very young animal is certainly within the bounds of plausibility for an allosauroid of this size. Thirdly, it gave a light-hearted, comedic element to performances and appearances, making the overall experience less threatening for audiences in general. This is a factor for some adults who feel intimidated by performances in a non-theatre environment (Bicknell and Fisher, 1994). The naughty puppy persona was observed by the team responsible for Hunter to go down well with a wide range of audiences. However, no formal evaluation was conducted for Hunter the dinosaur.

Hunter's antics included such set pieces as dancing the 'Hunter Shuffle'; stealing the Dinosaur Ranger's hat; back-scratching against any convenient tree, post, or person; attempting to steal people's lunches; and urinating while cocking his leg (with the help of a water bottle carried by the puppeteer). Hunter's interactions with the Dinosaur Rangers were also a key element in the performance.

Making Hunter 'real' was a complicated and skilled achievement, and is an area where cutting costs would have been highly detrimental to the whole venture. A professional puppeteer was able to bring in skills and techniques to enhance Hunter in ways

Figure 3.(A) Dino-Factor interview panel, (B) Puppeteer Izzy Hollis (image NCC 2017)

that a layperson operating the dinosaur would struggle to achieve.

A team of volunteer 'Dinosaur Rangers' (including author MN) were also recruited to accompany Hunter (Figure 4). Hunter visits occurred on an almost daily basis over a seven-month period. There was a core team of about ten regular Dinosaur Rangers, but 80 volunteers worked alongside Hunter in total. Their role was intended to ensure the safety of Hunter and onlookers in crowds and to distribute publicity materials and information about the exhibition. This included protecting the public from a half-blind dinosaur – there was very limited visibility from within the puppet, and the tail was unwieldy and at head height. Crowd control was the main priority for Rangers to ensure people didn't push, pull, or try to jump on Hunter, and to provide directions for the puppeteer, making them aware of hazards, uneven surfaces, and little children wanting to meet the dinosaur. Rangers would also answer questions and encourage people to visit the exhibition. The Rangers also assisted the puppeteer with getting in and out of the costume and transporting it to the performance location.

Figure 4. Volunteer Dinosaur Rangers preparing for an appearance at Trent Bridge Cricket Ground. (image NCC 2017)

The normal minimum number of Rangers was two, but it was possible for a single experienced Dinosaur Ranger to accompany Hunter on some occasions. Up to five Rangers were needed for crowd control at busy locations, so that one Ranger could still hand out leaflets and engage with people. It became apparent very quickly that the Dinosaur Rangers also had a valuable role to play in creating the character of Hunter, by performing as animal handlers/trainers, and trying to make a mischievous, yet highly dangerous, 'puppy' behave in public. This role-play element became even more important while accompanying Hunter on school and other educational visits (see below).

Maintenance

A number of repairs were required over the seven months of use, particularly to the soles of the feet and the cables operating the jaw. The only way to repair the cabling was to cut open the head and peel back the outer silicone rubber 'skin' and inner high-density sponge 'flesh' of the costume, to reveal the metal frame and mechanical workings inside the 'skull' (Figure 5). Replacement cables had to be custom made and installed. NCMG are indebted to a local classic motorbike enthusiast, John Birtles (Figure 5c), for assisting with these repairs for free. Most professional puppeteers make their own puppets, and this was an unexpected benefit of the 'Dino-Factor' recruitment process; our puppet operator was able to carry out all cosmetic repairs and to resole the feet of Hunter. By the end of a gruelling seven months of almost daily use, other areas of the body were also showing signs of wear-and-tear, indicating that we were close to the end of Hunter's useful lifespan (without major refurbishment).

Figure 5. Clockwise from top left, (A) Inside the 'skull', (B) MN learning dinosaur brain surgery, (C) John Birtles manufacturing custom built cables, (D) Izzy Hollis (puppeteer) completing cosmetic repairs. (images Martin Nunn 2017)

Additionally, there was wear-and-tear on the puppeteer. Being encased in a heavily-insulated 40kg foam structure placed a considerable physical strain on the operator, in terms of the weight and the temperature inside the costume (especially on hot summer days). In order to combat the heat strain, an ice-pack-filled waistcoat was purchased. However, in summer these could all melt during the first performance slot. Consequently, performance times were limited to a maximum of four 30-40 minute slots per day.

Marketing

Marketing efforts for the exhibition started in early 2016, well in advance of the 1 July 2017 opening, and continued until the close of the exhibition at the end of October 2017. Hunter made his first appearances for the marketing campaign in April 2017, alongside Chris Packham (television presenter and naturalist), who endorsed Dinosaurs of China (Figure 6).

Figure 6. Television presenter and naturalist Chris Packham with Hunter (image NCC 2017)

Between April and October 2017, Hunter appeared at 129 marketing events. These were mostly focused in Nottinghamshire, but there were wider regional appearances in Leicestershire, Derbyshire, and South Yorkshire, visiting cities, towns and villages between Leicester and Sheffield (north to south), as far east as Melton Mowbray and as far west as Derby.

Types of venues included shopping centres, museums, adult education venues, sports venues and events, theatrical events, fun days and carnivals, and many others (e.g. East Midlands Airport, Nottingham University) (Figure 7).

The specific activities during these appearances varied depending on the venue. Some locations such as shopping centres, carnivals, festivals, and museums revolved around Hunter mingling with crowds, and interacting with members of the public and the Rangers. At venues such as sports stadiums, or the Lord Mayor's parade, the public were mostly separated from Hunter. On these occasions, the focus was on Hunter performing and interacting with the Rangers, and when possible meeting audience members in the front row, especially children.

Hunter was popular, and generated a significant interest among the public and media. BBC Radio Nottingham posted a video of Hunter that received 14,000 views (EDEN, 2018). Hunter's social media presence on Facebook and Twitter was high, with regular updates. Hunter's most popular Facebook post reached 5,459 people (EDEN, 2018). Visitor surveys (University of Nottingham, 2017) conducted during the exhibition showed that 37% of those questioned had heard about the exhibition on social

Figure 7. (A) Hunter at Nottingham Forest FC Stadium on match day. (B) Hunter visiting a carnival. (Images NCC 2017)

media, with only 14% having heard about the exhibition through more traditional news sources and advertising. This clearly shows the growing importance of social media for the promotion of exhibitions, and Hunter influenced NCMG's utilisation of these new media outlets. However, word of mouth was the biggest awareness factor, at 49% (Figure 8). The survey also demonstrated that people were visiting from across the country (Table 1). Some visitors to the exhibition certainly attended as a direct result of an encounter with Hunter (MN pers. obs.).

Marketing leaflets and banners also capitalised on Hunter, and featured an artist's recreation of *Sinraptor* and feathered dinosaurs as they may have been in life (Figure 9). However, few fossil skeletons were depicted in the promotional material, as the marketing team believed that lifelike depictions of dinosaurs would be more likely to attract greater numbers of visitors.

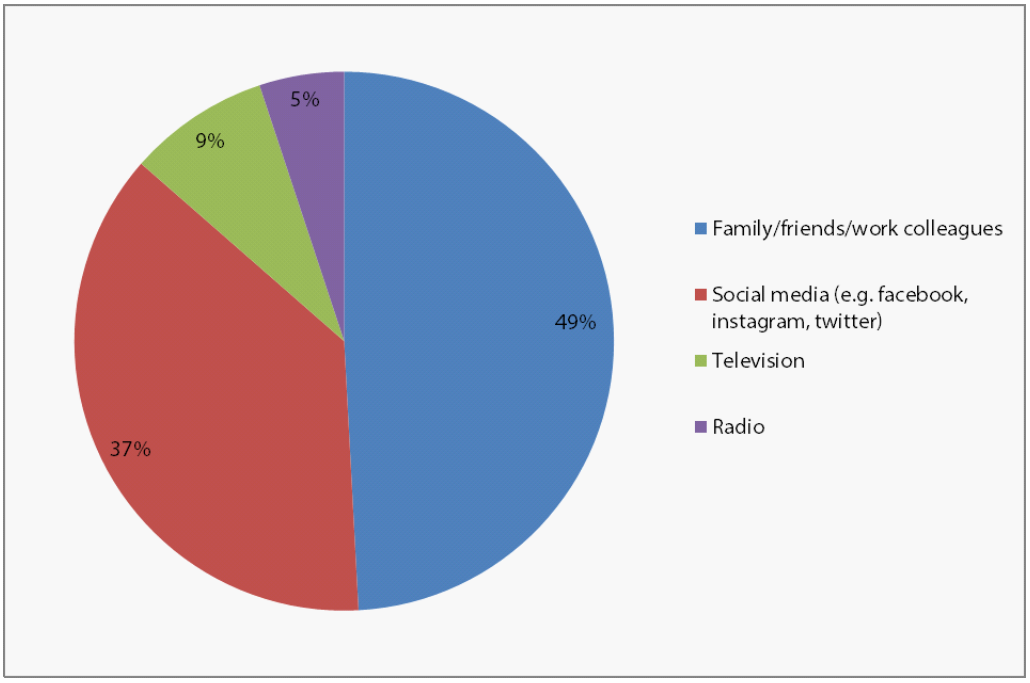

Figure 8. Visitor Survey responses to the question, 'How did you hear about the exhibition (tick all that apply)?'. Total count 118. Adapted from University of Nottingham, 2017.

Table 1. Visitor Survey, responses to the question 'Where have you travelled from today?'. Adapted from University of Nottingham, 2017.

Answer	**%**	**Count**	
Nottingham	50.68	75	
Derbyshire	23.65	35	
Leicestershire	10.81	16	**Other**
Lincolnshire	1.35	2	Milton Keynes
Cambridgeshire	2.03	3	Blackpool
Yorkshire	5.41	8	Birmingham
London	1.35	2	Hampshire
Other	4.73	7	Hertfordshire
			Gloucestershire
Total	100	148	Germany

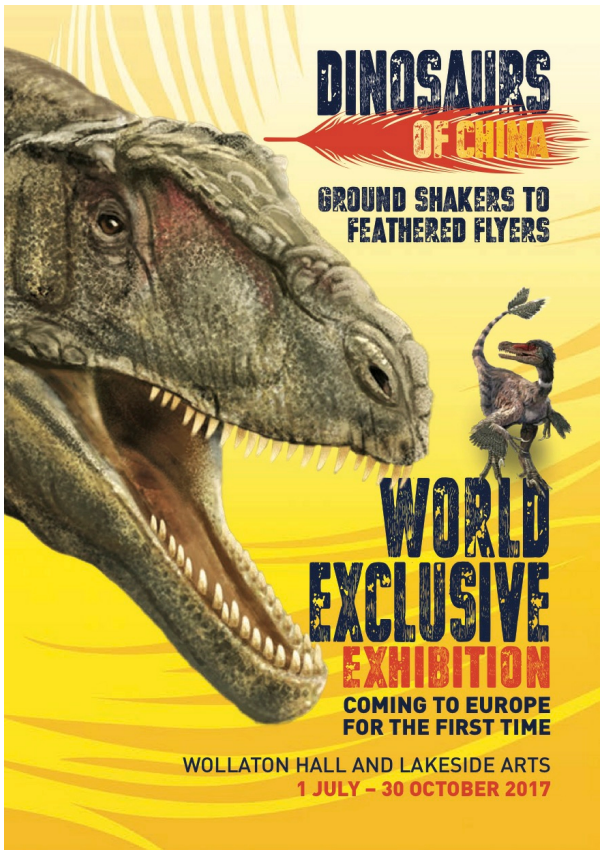

Figure 9. Example of marketing leaflet distributed by Dinosaur Rangers. (image NCC 2017)

Educational appearances

Primary school visits were initially viewed as a marketing tool aimed at the child demographic. Engagement with Hunter and the Rangers was high, and it soon became apparent that these visits were also an ideal opportunity to explore a range of biological and ecological topics. To enhance the connection between Hunter and the fossils in the exhibition, some Rangers adopted a dress and persona reminiscent of Roy Chapman Andrews (plus a little bit of lion tamer). This created a storyline and rationale for the school visits. A familiarity with Roy's life and his expeditions to China and Inner Mongolia was essential (Andrews, 1918; 1921; 1932). It also required a familiarity with non-avian dinosaurs in general, particularly theropods and the primary literature pertaining to *Sinraptor* (Yuhui 1992; Currie and Zhao, 1993; Currie, 2006; Carabajal and Currie, 2012; Fastovsky and Weishampel, 2012; Naish and Barrett, 2016; Paul, 2016). The person carrying out this role also needed to be a competent actor or role-player. It is quite a specific skill set, one described by Alsford and Parry (1991: p.18) as "actor-interpreters". Our experience concurs with those of Alsford and Parry (ibid), who assert that roles of this kind require research time and training.

The interaction between Hunter and 'Roy' often became a springboard for wider discussions and interactive Q&A sessions. Common topics covered in these sessions included predator-prey relationships, predator adaptations, dentition and dental growth, evolution of feathers, birds as dinosaurs, and ontogenetic change and growth rates. One of the most common questions during school visits was“how old is Hunter?”, asked in the context of whether he is an adult or a baby. In other words, how accurate is the puppet? This was actually one of the hardest questions to answer honestly and accurately.

Calculations from the published literature (e.g. Currie and Zhao, 1993; Christiansen and Farina 2004; Bybee, Lee and Lamm, 2006; Foster and Chure, 2006; Therrien and Henderson, 2007; Hendrickx and Mateus, 2012) demonstrate that Hunter's proportions are not consistent with those of a juvenile. Based on the puppet's measured height, skull length, and femur length, Hunter is close to a six-year-old animal. However, a six-year-old allosauroid would have a body length almost double that of the puppet, and would weigh about the same as a small racehorse. Based on body length, Hunter would be around three years old, but would only stand around a meter tall and would weigh about the same as a large dog. Overall, Hunter's size and proportions are closest to a heavily foreshortened six-year-old sub adult animal. However, we chose to represent Hunter as a three-year-old juvenile, characterised as a naughty puppy, which was an engaging narrative, especially with younger children. This was consistent with his length, but not his body proportions or height. In any case, the whole concept requires a suspension of disbelief, as Hunter was anthropomorphised a lot, and we ignored the fact that a real *Sinraptor* would likely rip apart and consume any Dinosaur Ranger and audience members at the drop of a hat.

24 primary schools were visited in the build-up to and during the exhibition. Most of these visits were one-off extended assemblies; however, a few schools did incorporate Hunter's visit into a wider programme of study on dinosaurs. Some schools followed up Hunter's visit with a trip to see the fossils at the Nottingham Natural History Museum (Wollaton Hall). Hunter's visits to schools were enjoyed by the children (Figure 10) and appreciated by the teaching staff.

Figure 10. Positive reactions to a school visit. (image NCC 2017)

Hunter at Wollaton Hall

Limited space and the risk of damaging the exhibits meant that Hunter was unable to appear inside the museum. However, a Dinosaurs of China educational activity marquee was operational each day outside the museum, and so Hunter made regular appearances there (Figure 11). Visitors and schools who interacted with Hunter around the education marquee reported that it heightened their enjoyment and made the visit more memorable for them (MN pers. obs.). Hunter's performances in this area increased over time as external marketing decreased, and as it became apparent that many visitors came to the exhibition hoping or expecting to see animatronic dinosaurs. In total, Hunter made 136 separate performances outside Wollaton Hall.

Impact on visitor expectations

The response to Hunter was overall positive (except for a few dogs!), and it helped raise awareness about the exhibition (EDEN, 2018). Volunteers unanimously reported that Hunter was great for 'creating a buzz', and he was very popular for photo opportunities with the press and the public (EDEN, 2018).

Using a large theatrical prop is certainly an approach that NCMG would utilise with future exhibitions. However, care needs to be taken with marketing, as a few visitors did come expecting to see a theatrical extravaganza of animatronic dinosaurs and were disappointed when confronted with the actual dinosaur fossils. Hunter may have contributed to these erroneous expectations. A greater emphasis on fossils and skeletons, with collections at the forefront of marketing, could result in a more balanced and realistic set of expectations.

Lessons for the future

The educational potential of Hunter was not initially recognised, but was applied as much as possible later during the Dinosaurs of China project. It would be

Figure 11. (A) Hunter at Wollaton Hall outside the activity marquee (image NCC 2017) (B) Children enjoying hands on extension activities to the Dinosaurs of China exhibition. (image Martin Nunn 2017).

beneficial for similar endeavours to look closely at how marketing and educational objectives can both be met early in the planning phase. There is a wide array of potential educational uses for puppetry in a science exhibition that could be investigated in any future projects. For example, longer school visits to allow a deeper dive into the subject matter, and encouraging schools (through the supply of teaching resources and lesson plans) to incorporate the topic into their teaching and not view a visit as a one-off activity. As noted above, Behrendt and Franklin (2014) stressed how important this ongoing engagement of teachers is, from planning to reflection, for the beneficial attributes of a field trip to be maximised.

Furthermore, advanced planning for educational content during school visits would have allowed for key learning objectives to be incorporated into these activities. For example, key messages in the exhibition related to our changing understanding of dinosaur ecology, in particular the prevalence of feathers and the relationship with birds. These could have been formalised into a school visit through the use of a second small feathered dinosaur puppet, accompanying Hunter. This would have helped reinforce the latest developments in palaeontological research in this area. The feasibility of conducting formal evaluations of these visits should also be considered.

Another possible approach would be using the puppet or other theatrical techniques with museum visitors to complement the interpretation within the exhibition. The goals would be to stimulate a deeper engagement and interest in the scientific questions, lengthen gallery dwell times, and encourage a more detailed examination of the museum exhibits. Based on previous studies and our own experience, such a balance is achievable with careful planning and allocation of resources.

A human companion (the role of our Dinosaur Rangers) is key to engaging with an audience when a character, like the puppet Hunter, is unable to communicate verbally with the audience. When engaging in an educational setting, this person needs to have a high level of detailed scientific knowledge on the subject matter, a high proficiency in science communication, and an ability to interact naturally and realistically with the puppet. In short, they need to be able to fulfil the role of actor interpreter as defined by Alsford and Parry (1991: p.18). Recruitment of a suitable person would best be carried out at the same time as recruitment of the puppeteer.

It is clear that there is a strong role for drama in science education, and NCMG's use of Hunter is therefore another example of a successful integration of these two paradigms.

Acknowledgements

We thank Wang Qi for being the inspiration behind the exhibition; Izzy Hollis for bringing Hunter to life; all of the volunteers who accompanied Hunter on visits; Rebecca Wilson and Karen Lushy for coordinating Hunter's appearances; Rachael Evans for her help supplying data, clarifying issues, and proof reading; Graham Armitage and all of the heritage assistants at Wollaton Hall; and John Birtles for making Hunter roar again!

References

Alsford, S. and Parry, D. 1991. Interpretive theatre: a role in museums*? Museum Management and Curatorship*, 10, pp.8-23.

Andrews, R.C., 1918. *Camps and Trails in China. A narrative of exploration, adventure and sport in little known China*. New York: D. Appleton and Company. [online] Available at: <https://archive.org/details/campsandtrailsi00unkngoog/page/n6> [Accessed 16 November 2018].

Andrews, R.C., 1921. *Across Mongolian Plains. A naturalist's account of Chinas great northwest*. New York: D. Appleton and Company. [online] Available at: <https://archive.org/details/acrossmongolianp00andr/page/n9> [Accessed 16 November 2018].

Andrews, R.C., 1932. *The new conquest of Central Asia. A narrative of the explorations of the Central Asiatic expeditions in Mongola and China, 1921-1930*. New York: The American Museum of Natural History. [online] Available at: <https://archive.org/details/newconquestofcen00andr/page/n9> [Accessed 16 November 2018].

Anthony, A., 2018. *Palaeontologist Steve Brusatte: we owe Jurassic Park a debt of gratitude*. [online] Available at: <https://www.theguardian.com/science/2018/may/13/steve-brusatte-palaeontologist-debt-gratitude-jurassic-park> [Accessed on 16 November 2018].

Baum, L. and Hughes, C., 2001. Ten Years of evaluating science theatre at the Museum of Science Boston. *Curator, The Museum Journal*, 44(4), pp.355-366.

Behrendt, M. and Franklin, T., 2014. The review of research on school field trips and their value in education. *International Journal of Environmental & Science Education*, 9, pp.235-245.

Benton, M.J., Zhou, Z., Orr, P.J., Zhang, F., and Kearns, S.L., 2008. The remarkable fossils from the Early Cretaceous Jehol Biota of China and how they have changed our knowledge of Mesozoic life. *Proceedings of the Geologists' Association*, 119, pp.209-228.

Bicknell, S. and Fisher, S., 1994. Enlightening or embarrassing? Drama in the Science Museum, London, UK. *Visitor Studies*, 6(1), pp.79-88.

Bruner, J., 1992. Science education and teachers: a Karplus Lecture. *Journal of Science Education and Technology*, 1(1), pp.5-12.

Bybee, P.J., Lee, A.H., and Lamm, E-T., 2006. Sizing the Jurassic theropod dinosaur *Allosaurus*: Assessing growth strategy and evolution of ontogenetic scaling of limbs. *Journal of Morphology*, 267, pp.347-359.

Carabajal, A.P. and Currie P.J., 2012. New information on the braincase of *Sinraptor dongi*. *Vertebrata Pal. Asiatica*, 50(10), pp.85-101.

Chatterjee, S. and Templin, R.J., 2012. Palaeoecology, aerodynamics, and the origin of flight. In: Talent, J.A. (ed). *Earth and Life*. Heidelberg: Springer-Verlag. pp.585-612.

Chemi, T. and Kastberg, P., 2015. Education through theatre: typologies of science theatre. *Applied Theatre Research*, 3(3), pp.53-65.

Chen, P.J., Dong, Z.M., and Zhen, S.N., 1998. An exceptionally well preserved theropod dinosaur from the Yixian Formation of China. *Nature*, 391, pp.147-152.

Christiansen, P. and Farina, R.A., 2004. Mass prediction in theropod dinosaurs. *Historical Biology*, 16(2-4), pp.85-92.

Chiappe, L.M., 2004. The closest relatives of birds. *Ornitologica Neotropical*, 15(Suppl.), pp.101-116.

Cornell, J.B., 1979. *Sharing nature with children*. Nevada City, US: Dawn Publications.

Cornell, J.B., 1989. *Sharing the joy of nature*. Nevada City, US: Dawn Publications.

Currie, P.J., 2006. On the quadrate of *Sinraptor dongi* (Theropoda: Allosauroidea) from the late Jurassic of China. In: Cziki, Z., (ed.). *Mesozoic and Cenozoic vertebrates and paleoenvironments. Tributes to the career of Prof. Dan Grigorescu*. Bucharest: Editura Ars Docendi. pp.111-115.

Currie, P.J. and Zhao, X.J., 1993. A new carnosaur (dinosaur, Theropoda) from the Jurassic of Xinjiang, People's Republic of China. *Canadian Journal of Earth Sciences*, 30(10), pp.2037-2081.

Dorion, K.R., 2009. Science through drama: a multiple case exploration of the characteristics of drama activities used in secondary science lessons. *International Journal of Science Education*, 31(16), pp.2247-2270.

EDEN Public Relations Consultants, 2018) Campaign review. [unpublished report]

Emmett, J., 2018. *How the Borks became*. Burley Gate: Otter-Barry Books Ltd.

Fastovsky, D.E. and Weishampel, D.B., 2012. *Dinosaurs: A Concise Natural History (2nd Edition)*. Cambridge: Cambridge University Press.

Foster, J.R. and Chure, D.J., 2006. Hind limb allometry in the Late Jurassic theropod dinosaur Allosaurus, with comments on its abundance and distribution. In: Foster, J.R. and Lucas, S.G. (eds). *Paleontology and Geology of the Upper Jurassic Morrisson Formation. New Mexico Museum of Natural History and Science Bulletin 36*. pp.119-122.

Granger, W. and Gregory, W.K., 1923. *Protoceratops andrewsi*, a pre-ceratopsian dinosaur from Mongolia. *American Museum Novitates*, no.72.

Hawking, L. and Hawking, S., 2008. *George's secret key to the universe*. Corgi Children's.

Hendrickx, C. and Mateus, O., 2012. Ontogenetical changes in the quadrate of basal tetanurans. In: Royo-Torres, R., Gascó, F., and Alcalá, L., (coord). *10th Annual Meeting of the European Association of Vertebrate Palaeontologists. ¡Fundamental!*, 20, pp.101–104.

Hone, D., 2010 Dinosaurs of a feather. *Bulletin of the Chinese Academy of Sciences*, 2, pp.92-94.

ITV, 2017. *Casting call for city's dinosaur - do you have the 'Dino-Factor'?* ITV Report 20 March at 1:30pm. [online] Available at: <http://www.itv.com/news/central/2017-03-20/casting-call-for-citys-dinosaur/> [Accessed 16 November 2018].

Johns, B., 2017. *Dinosaur handlers being recruited for Wollaton Hall exhibition*. Notts T.V. April 26. [online] Available at: <https://nottstv.com/dinosaur-handlers-recruited-wollaton-hall-exhibition/> [Accessed 16 November 2018].

Kind, P.M., and Kind, V., 2007. Creativity in science education: Perspectives and challenges for developing school science. *Studies in Science Education*, 43, pp.1-37.

Klein, P.D., 2006. The challenges of Scientific Literacy: from the viewpoint of second generation cognitive science. *International Journal of Science Education*, 28(2-3), pp.143-178.

Ledgard, A., 2008. Visiting Time and Boychild: site-specific pedagogical experiments on the boundaries of theatre and science. In: Parry, S., Matterson, C., Nicholson, H., Winston, J., Caccavale, E., Reiss, M., Lotto, R.B., Downham, S.J., Strudwick, D., Heppell, S., Pinching, A., Teare, J., Turley, S., Ledgard, A., Levinson, R., Barton, A.C., O'Neill, T., Chappell, K., McNamara, C., and Rooke, A., 2008. *Creative Encounters: New conversations in science, education and the arts*. London: Wellcome Trust.

McCallie, E., Bell, L., Lohwater, T., Falk, J.H., Lehr, J.L., Lewenstein, B.V., Needham, C., and Wiehe, B., 2009. Many Experts, Many Audiences: Public Engagement with Science and Informal Science Education. A CAISE Inquiry Group Report. Washington, D.C.: Center for Advancement of Informal Science Education (CAISE). [online] Available at: <http://caise.insci.org/uploads/docs/public_engagement_with_science.pdf>.

McSharry, G., and Jones, S., 2000. Role-play in science teaching and learning. *School Science Review*, 82(298), pp.73-82.

Mesure, S., 2005. Creativity in science: the heart and soul of science teaching. *Education in Science*, 214, pp.12-14.

Naish, D. and Barrett, P., 2016. *Dinosaurs: How they lived and evolved*. London: Natural History Museum.

Odegaard, M., 2003. Dramatic science. A critical review of drama in science education. *Studies in Science Education*, 39, pp.75-102.

Osborn, H.F., 1924. Three new theropoda, Protoceratops zone, Central Mongolia. *American Museum Novitates*, 144, pp.1-12.

OkurBerberoglu, E., Ozdilek, S.Y., Sonmez, B., and Olgun, O.S., 2014. Theatre and sea turtles: an intervention in biodiversity education. *International Journal of Biological Education,* 3(1), pp.24-40.

Pan, Y., Sha, J., Zhou, Z., and Fursich, F.T., 2013. The Jehol Biota: Definition and distribution of exceptionally preserved relics of a continental Early Cretaceous ecosystem. *Cretaceous Research*, 44, pp.30-38.

Papalaskari, M.A., Hess, K., Kossman, D., Metzger, S., Phares, A., Styer, R., Titone, C., Way, T., Weinstein, R., and Wunderlich, F., 2006. PIVOTS: Service learning at the science, theatre & magic boundary. *Proceedings of the 36th ASEE/IEEE Frontiers in Education Conference*.

Paul, G.S., 2016. *The Princeton Field Guide to Dinosaurs, 2nd Edition*. Princeton: Princeton University Press.

Peleg, R., and Baram-Tsabari, A. 2011. Atom Surprise: using theatre in primary science education. *Journal of Science Education and Technology*, 20(5), pp.508-524.

Sekiya, T. and Dong, Z., 2010. A New Juvenile Specimen of *LufengosaurusHuenei* Young, 1941 (Dinosauria: Prosauropoda) from the Lower Jurassic Lower Lufeng Formation of Yunnan, Southwest China. *Journal of the Geological Society of China*, 84(1), pp.11-21. [online] Available at: <https://doi.org/10.1111/j.1755-6724.2010.00165.x> [Accessed 16 November 2018].

Smith, A. and Qi, W., 2017. *Dinosaurs of China: ground shakers to feathered flyers*. Nottingham: Nottingham City Council.

Smith, A. and Qi, W., In prep.. From China to Nottingham: The Making of Dinosaurs of China. *Journal of Natural Science Collections*. (Accepted for publication January 2019).

Smithwick, F.M., Nicholls, R., Cuthill, I.C., and Vinther, J., 2017. Countershading and stripes in the theropod dinosaur *Sinosauropterix* reveal heterogeneous habitats in the Early Cretaceous Jehol Biota. *Current Biology*, 27, pp.1-7.

Therrien, F. and Henderson, D.M., 2007. My theropod is bigger than yours...or not: body size from skull length in theropods. *Journal of Vertebrate Paleontology*, 27(1), pp.108-115.

Tselfes, V. and Paroussi, A., 2009. Science and theatre education: A cross-disciplinary approach of scientific ideas addressed to student teachers of

early childhood education. *Science and Education*, 18(9), pp.1115-1134.

University of Nottingham, 2017. *Dinosaurs of China Wollaton Hall Visitor Survey, 8th-17th August*. [unpublished report]

Whitesell, E.R., 2016. A day at the museum: the impact of field trips on middle school science achievement. *Journal of Research in Science Teaching*, 53(7), pp.1036-1054.

Xu, X. and Norell, M.A., 2004. A new troodontid dinosaur from China with avian-like sleeping posture. *Nature*, 431, pp.838-841.

Xu, X., Tan, Q., Wang, J., Zhao, X., and Tan, L., 2007. A gigantic bird-like dinosaur from the Late Cretaceous of China. *Nature*, 447, pp.844-847.

Xu, X., Wang, X.L., and Wu, X.C., 1999. A dromaeosaurid dinosaur with a filamentous integument from the Yixian Formation of China. *Nature*, 401, pp.262-266.

Xu, X., Zheng, X., Sullivan, C., Wang, X., Xing, L., Wang, Y., Zhang, X. O'Connor, J.K., Zhang, F., and Pan, Y., 2015. A bizarre Jurassic maniraptoran theropod with preserved evidence of membranous wings. *Nature*, 521, pp.70-73.

Xu, X., Zhou, Z., and Prum, R.O., 2001. Branched integumental structures in *Sinornithosaurus* and the origin of feathers. *Nature*, 410, pp.200-203.

Xu, X., Zhou, Z., Wang, X., Kuang, X., Zhang, F., and Du, X., 2003. Four-winged dinosaur from China. *Nature*, 421, pp.335-340.

Young, C.C. and Zhao, X., 1972. *Mamenchisaurus*. *Institute of Vertebrate Paleontology and Paleoanthropology Monograph Series I, No 8* (in Chinese). Translation available at: <http://doc.rero.ch/record/31573/files/PAL_E844.pdf>.

Yuhui, G., 1992. *Yangchuanosaurus hepingensis* - a new species of carnosaur from Zigong, Sichuan. *Vertebrata Pal Asiatica*, 30, pp.313-324 (in Chinese). Translation available at: <https://paleoglot.org/files/Gao_92a.pdf>.

Zhang, F., Kearns, S.L., Orr, P.J., Benton, M.J., Zhou, Z., Johnson, D., Xu, X., and Wang, X., 2010. Fossilized melanosomes and the colour of Cretaceous dinosaurs and birds. *Nature*, 463, pp.1075-1078.

Zhang, F., Zhou, Z., Xu, X., Wang, X., and Sullivan, C., 2008. A bizarre Jurassic maniraptoran from China with elongate ribbon-like feathers. *Nature*, 455, pp.1105-1108.

Zhou, Z., 2004. The origin and early evolution of birds: discoveries, disputes, and perspectives from fossil evidence. *Naturwissenschaften*, 91, pp.455-471.

Zhou, Z., 2006. Evolutionary radiation of the Jehol Biota: chronological and ecological perspectives. *Geological Journal*, 41, pp.377-393.

Zhou, Z., 2014. The Jehol Biota, an Early Cretaceous terrestrial Lagerstatte: new discoveries and implications. *National Science Review*, 1, pp.543-559.

Zhou, Z., Barrett, P.M., and Hilton, J., 2003. An exceptionally preserved Lower Cretaceous ecosystem. *Nature*, 421, pp.807-814.

Zhou, Z. and Wang, Y., 2010. Vertebrate diversity of the Jehol Biota as compared with other lagerstatten. *Science China Earth Sciences*, 53(12), pp.1894-1907.