

<b>Institution:</b> University of Kent		
<b>Unit of Assessment:</b> 22: Anthropology and Development Studies		
<b>Title of case study:</b> Improving Learning and Understanding of Human Evolution in Museums and Schools Globally		
<b>Period when the underpinning research was undertaken:</b> 2013-2020		
<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 HEI:</b>
Prof. Tracy Kivell	Professor of Biological Anthropology	February 2013-present
Prof. Matthew Skinner	Professor of Biological Anthropology	November 2014-present
<b>Period when the claimed impact occurred:</b> 2014-2020		
<b>Is this case study continued from a case study submitted in 2014?</b> No		
<b>1. Summary of the impact</b>		
<p>Collaborative research by Professors Kivell and Skinner on recently discovered human fossils – <i>Australopithecus sediba</i> and <i>Homo naledi</i> – led to the creation of diverse educational materials and events. These material and events have been disseminated through a variety of educational settings in Tanzania, Kenya, South Africa, the USA, and the UK. The sharing of these novel pedagogical resources has changed the understanding of human prehistory, inspired novel engagement with human evolution, and reconnected people to their cultural heritage across these international locations. In addition, by working with beneficiaries in specialist education and outreach roles throughout East and South Africa, the USA, and the UK, including curation and curriculum development, the Kent Biological Anthropology research team has improved knowledge and museum practice globally.</p>		
<b>2. Underpinning research</b>		
<b>Overview</b>		
<p>Contemporary understanding of human prehistory is based largely upon rare and often fragmentary fossils. For almost a century, the evolution of humans has been summarised as a transition from small-brained bipeds, with an ape-like body plan (referred to as australopiths), to large-brained, striding bipeds, with a human-like body plan (members of the genus <i>Homo</i>). However, Skinner and Kivell's research on fossil human (hominin) species, including two hominins newly discovered in South Africa – <i>Australopithecus sediba</i> in 2010 and <i>Homo naledi</i> in 2015 – has shown that this simple transitional model of human evolution is no longer supported by fossil evidence. Through studies of the external morphology and, in particular, analyses of the internal structures of bones and teeth, their research has revealed novel insights into the evolutionary relationships among different species, and unexpected locomotor and manipulative abilities that reveal a more complex and exciting human evolutionary story.</p>		
<b>Research</b>		
<p>Since 2015, Kivell and Skinner have developed a significant body of research that focuses on descriptions of recently discovered fossil hominin species. This body of work includes studies of <i>Australopithecus sediba</i> [R6] and <i>Homo naledi</i> [R1, R5]; the analysis of new fossils from existing species, including Neandertals [R4]; and novel analyses of known fossils, looking at the internal structure of the bones [R2, R6] and teeth [R3, R4] for the first time.</p>		

The University of Kent-based research was supported by two ERC grants: Kivell's Starting Grant (2014-19) and Skinner's Consolidator Grant (2019-24), for which each were PIs. Collectively, the research focuses on the evolutionary information that can be derived from fossil teeth [R1, R3, R4], as well as the evolution of locomotion (e.g. bipedalism, climbing) and tool-related behaviours that can be derived from the skeleton [R1, R2, R5, R6].

Much of the research is based on state-of-the-art analyses of the internal structure of living and fossil primate bones and teeth through high-resolution microCT scanning, and Skinner and Kivell have amassed the largest comparative microCT data set of hominin fossils in the world [R2, R3, R4, R6]. This research is couched within a necessarily broader comparative context that includes analyses of tooth and bone structure in living apes (e.g. chimpanzees, gorillas, and orangutans) and humans; behavioural and biomechanical studies of how living apes move within their environment; and biomechanical studies of human tool-making and tool-use.

Kivell and Skinner's research is improving our understanding of human evolutionary history, highlighting a much broader diversity of skeletal and dental morphologies, and, in turn, inferred behaviours in our fossil human ancestors. In particular, it has highlighted the use of human-like manipulative abilities in much earlier fossil hominins than previously thought [R2]; the use of tree-climbing (arboreal) abilities in hominins much later than previously thought [R5, R6]; and a greater diversity in the ways in which our ancestors walked on two feet.

### 3. References to the research

As PIs, Kivell and Skinner led inter-institutional and international research groups, including collaborators from South Africa, Germany, Austria, Canada, the USA, and the UK. All work, specifically on hand morphology and internal tooth structures, was conducted at Kent with Kivell and/or Skinner as the lead, and other Kent contributing staff, including early career researchers Bardo and Dunmore.

[R1] Berger, L. R., Hawks, J., de Ruiter, D. J., Churchill, S. E., Schmid, P., Delezene, L. K., Kivell, T. L., Garvin, H. M., Williams, S. A., DeSilva, J. M., Skinner, M. M., Musiba, C. M., Cameron, N., Holliday, T. W., Harcourt-Smith, W., Ackermann, R. R., Bastir, M., Bogin, B., Bolter, D., Borphy, J., Cofran, Z. D., Congdon, K. A., Deane, A. S., Dembo, M., Drapeau, M., Elliot, M. C., Feuerriegel, E. M., Garcia-Martinez, D., Green, D. J., Gurtov, A., Irish, J. D., Kruger, A., Laird, M. F., Marchi, D., Meyer, M. R., Nalla, S., Negash, E. W., Orr, C. M., Radovic, D., Schroeder, L., Scott, J. E., Throckmorton, Z., Tocheri, M. W., VanSickle, C., Walker, C. S., Pianpian, W., and Zipfel, B. (2015). 'Homo naledi, a new species of the genus Homo from the Dinaledi Chamber, South Africa'. *eLife*: 1-35. doi: 10.7554/eLife.09560

[R2] Skinner, M. M., Stephens, N., Tsegai, Z. J., Foote, A., Nguyen, N. H., Gross, T., Pahr, D. H., Hublin, J.-J., and Kivell, T. L. (2015). 'Human-like hand-use in the hand of *Australopithecus africanus*'. *Science* 347(6220): 395-399. doi: 10.1126/science.1261735

[R3] Zanolli, C., Kullmer, O., Kelley, J., Bacon, A.-M., Demeter, F., Dumoncel, J., Fiorenza, L., Grine, F.E., Hublin, J.-J., Nguyen, A.T., Nguyen, T. M. H., Pan, L., Schillinger, B., Schrenk, F., Skinner, M. M., Ji, X., and Macchiarelli, R. (2019). 'Evidence for increased hominid diversity in the Early to Middle Pleistocene of Indonesia'. *Nature Ecology and Evolution* 3: 755-764. doi: 10.1038/s41559-019-0860-z

[R4] Martin, R. M. G., Hublin, J.-J., Gunz, P., and Skinner, M. M. (2017). 'The morphology of the enamel-dentine junction in Neanderthal molars: Gross morphology, non-metric traits, and temporal trends'. *Journal of Human Evolution* 103: 20-44. doi: 10.1016/j.jhevol.2016.12.004

[R5] Kivell, T. L., Deane, A. S., Tocheri, M. W., Orr, C. M., Schmid, P., Hawks, J., Berger, L. R., and Churchill, S. E. (2015). 'The hand of *Homo naledi*'. *Nature Communications* 6 (8431): 1-9. doi: 10.1038/ncomms9431

[R6] Dunmore, C. J., Skinner, M. M., Bardo, A., Berger, L. R., Hublin, J.-J., Rosas, A., Stephens, N. B., Kivell, T. L. (2020). 'The position of *Australopithecus sediba* in fossil hominin hand-use diversity'. *Nature Ecology and Evolution* 1-8. doi: 10.1038/s41559-020-1207-5

This research has been supported by two European Research Council grants focusing on the evolution of the human hand (Starting Grant, PI: Kivell; senior staff: Skinner, GRASP project #336301, 2014-19); and on evolution of the skeleton more broadly (Consolidator Grant, PI: Skinner; senior staff: Kivell, NEWHUMAN project #819960, 2019-24).

#### 4. Details of the impact

##### Informing Museum Practice

Kivell and Skinner's research on fossil hominins, including the two recently discovered fossil human species in South Africa (*Australopithecus sediba*, 2010 and *Homo naledi*, 2015), has involved sustained, close collaboration with partners in museums, HEIs, and cultural institutions in South Africa, Tanzania, and Kenya, as well as in the UK and USA.

Their work has had a significant impact on museum practice in these regions, through providing more accurate data on key fossils, ongoing knowledge-sharing, and the provision of learning resources. Their contributions to museums have included updated information on known fossils and new discoveries, as well as 3D-printed replicas of fossils and living apes created from their digital microCT datasets. Becca Peixotto, Director of the Centre for the Exploration of the Human Journey at the Perot Museum of Nature and Science, describes how: 'Tracy [Kivell] has led the original fossil descriptions and research on the *Australopithecus sediba* and *Homo naledi* hands, which has fundamentally changed the way we think about the evolution of the human hand in relation to both tool use and the evolution of bipedalism. Matt's [Skinner] work has been critical to understanding the evolutionary relationship these new fossils have to other fossil human species, as well as their age and health' [c]. This is echoed by Agness Gidna, Curator of Palaeontology at the National Museum of Tanzania, who describes how the research has 'had an obvious impact on my curatorial practice, allowing me to provide a more holistic view of human evolution to our visitors' [a].

##### Transforming Visitor Interpretation

Kivell and Skinner have created a more scientifically accurate, inclusive, and engaging model for presenting curated materials on human evolution – one that is serving to challenge broader misconceptions about the scientific basis of evolutionary research. In 2017, they began to develop a range of interactive public educational materials based on the fossil species that are central to their research, including *Australopithecus sediba* [R2, R6], *Homo naledi* [R1, R5] (South Africa), early *Homo* [R3] (Tanzania, Kenya, and Asia), and Neandertals [R4] (Europe). The educational materials include an interactive activity sheet for each of these four species, with a pop-out figurine and fact sheet, a human evolution board game and activity book, various fossil replicas, and a video, *How Do Our Hands Make Us Human?* [g].

Since 2019, the educational materials have been used for visitors at the Tanzanian National Museum; the Origins Centre Museum, the Maropeng Museum, and the Visitor Centre at the Cradle of Humankind in South Africa (a UNESCO World Heritage site); and in the Community Outreach programmes of the Turkana Basin Institute in Kenya [a, b, c, d]. Bonita de Klerk of the Evolutionary Studies Institute in Johannesburg said: 'The educational materials that Matt [Skinner] and Tracy [Kivell] have developed on the basis of their research have been invaluable for helping to engage students in human evolution and the important fossils of South Africa' [d]. This is echoed by Agness Gidna at the National Museum of Tanzania, who felt the impact of the materials on her students was 'clear [as] they are learning, most often for the first time, about the deep history of human evolution by being able to touch and hold the fossil evidence' [a].

In the USA, Kivell and Skinner's educational materials were used at the Perot Museum, Texas,

where many deny evolution. The exhibition 'Origins: Fossils from the Cradle of Humankind' (October 2019-March 2020) included their research on *A. sediba* [R2, R6] and *H. naledi* [R1, R5]. As the curator commented, the accompanying educational materials, which she has disseminated to over 30 educators, 'have been invaluable for helping to engage students, families, and educators in human evolution [...] particularly in the context of persistent attitudes in Texas toward human evolution' [c].

In the UK, Kivell and Skinner worked with museum staff to develop two exhibitions based on their research: *Me, Human*, through the Live Science initiative at the London Science Museum (2,000 visitors, July-September 2019); and *Meet your Fossil Ancestors*, at the Beane House of Art and Knowledge, Canterbury (May-June 2019). The Beane House exhibition was attended by 4,600 visitors (compared with ~2,500 the year before), of whom nearly 75% said they 'learned a great deal' and 50% were 'not previously aware of how much fossil evidence there was' for human evolution [f].

### Improving Children's Understanding of Heritage in South and East Africa

Although African countries curate the majority of fossils related to human origins, students receive little, if any, exposure to this important aspect of their cultural and national heritage, and materials used to teach human evolution in schools are often outdated, inaccurate, and do not engage children [a, c]. In 2017, Kivell and Skinner started creating an educational package [g] that has provided schoolchildren and teachers in Tanzania, Kenya, and South Africa with more accurate and engaging information of the human evolutionary story. Crucially, their materials have helped children and teachers alike to gain a new appreciation of their own national heritage. As Agness Gidna (National Museum of Tanzania) states: 'They have gained a new appreciation of their national heritage, something I personally consider priceless' [a].

Through the National Museum of Tanzania's outreach programme, these teaching materials have been distributed to, and used by, over 950 schoolchildren aged 10-13 years at 12 different schools in Dar es Salaam since 2019 [a]. Pupils have commented: 'The materials are more actual and interactive, it makes us not to forget even when we are away from museum and school'; and 'It makes me understand and interested in human evolution topics' [a].

Describing the teaching resources, Agness Gidna said: 'they are learning about the critical role that Tanzania in particular, and Africa as a whole, has played in our understanding of human evolution [...]. The impact of the educational resources has been immense, not only for the students, but also for me as an educator' [a].

In South Africa, the educational materials have been distributed to primary and high schools in Johannesburg, including those in disadvantaged communities, through the researchers' collaboration with the University of the Witwatersrand [d]. Importantly, they have also been translated into Zulu, Tswana, and Afrikaans, enabling marginalised and harder-to-reach communities to engage in the research: 'Being able to learn in your home language [...] allows students to fully embrace and understand a story that is common to us all' [d].

In Kenya, the educational materials have been adopted by the Turkana Basin Institute, Nairobi, where they have been integrated into Community Outreach education programmes. Local teachers are 'excited about the materials' and 'come to the facility to ask questions' [b].

### Supporting Curriculum Development in HEIs

Kivell and Skinner's research is influencing curriculum development in HEIs within the broader field of biological anthropology. In an international survey of 43 academics teaching human evolution (2020) in the UK, Europe, and North America, over 90% of respondents used *A. sediba* [R2, R6] and *H. naledi* [R1, R5] hand research in their teaching. Examples of feedback comments include statements that the research has 'changed the way I teach and also think about my research questions', and that students 'can relate to [hand evolution] better than

changes in genes, which they cannot see themselves' [e].

Kivell and Skinner's work is cited in eight widely used university textbooks across North America and the UK, including *Primate Behavioural Ecology* (Strier, 2017), and their development of an educational digital archive (250+ registered users) has facilitated online learning globally.

### Engaging and Informing the Wider Public

Kivell and Skinner have improved wider public understanding and knowledge of human evolution. They have organised and taken part in a range of events to improve science communications, including Soapbox Science, which promotes women scientists and their research to the public (2017, 2018, 2019), and events in partnership with the Natural History Museum and the Royal Institution. Their work has appeared in popular science books such as *Primate Change: How the World We Made is Remaking Us* (Octopus, 2018) and *The Incredible Unlikelihood of Being* (Heron Books, 2014). Kivell participated in the BBC documentary series *Dissected: The Incredible Hand and Foot* (February 2014), and the pair's research has featured in popular science articles in *Science* (January 2015), *National Geographic* (January 2015), *Discover* magazine (November 2015), and *New Scientist* (May 2018). The *Homo naledi* research was ranked #2 in *Discover* magazine's '100 top stories of 2015' and runner-up in *Science*'s 'Breakthrough of the Year' in December 2015.

### 5. Sources to corroborate the impact

[a] Testimonial: Curator of Palaeontology, National Museum and House of Culture, National Museum of Tanzania, Dar es Salaam, Tanzania. Describes the impact of Kivell and Skinner's research on students and pedagogy in Tanzanian schools.

[b] Emails: Community Development Manager (Turkana and Marsabit Counties), Turkana Basin Institute, Nairobi, Kenya. Describes the impact of Kivell and Skinner's research on the local community in Nairobi and northern Kenya.

[c] Testimonial: Director and Research Scientist, Center for the Exploration of the Human Journey, Perot Museum, Dallas TX, USA. Describes the impact of Kivell and Skinner's research on museum visitors and local educators of human evolution.

[d] Testimonial: Laboratory Manager, Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa. Describes the impact of Kivell and Skinner's research on museum visitors and local schools, including translation of materials into different languages.

[e] Survey: University curriculum impact survey results, sampling academics who teach human evolution throughout the UK, USA, and Europe, November-December 2020.

[f] Survey: Beane House of Art and Knowledge (Canterbury) exhibition survey results and visitors count. Provides results of in-person surveys completed by visitors to the exhibit between 28 May-2 June 2019 and visitor count compared to same week in 2018.

[g] Educational materials: <https://www.kent.ac.uk/anthropology-conservation/news/4305/human-evolution-educational-materials-now-available-to-download>. These consist of an Activity Book, a Board Game, as well as Facts and Activity Sheets for four different species of fossil human ancestors (hominins): *Australopithecus sediba*, *Homo neanderthalensis*, *Homo naledi*, and *Homo habilis*, with pop-out figurines and fold-up landscapes for each.