Understanding Insects: Why Explore Through Science And Art

Conference Paper · February 2014

2 authors:

Eleanor Gates-Stuart
Australian National University

Chuong V Nguyen
Australian National University

Understanding Insects: Why Explore Through Science And Art?

Eleanor Gates-Stuart[1], Chuong Nguyen[2]
Presenting Author: Eleanor Gates-Stuart (eleanor.gatestuart@anu.edu.au)
[1]Australian National Centre for the Public Awareness of Science, Australian National University, ACT 0200, Australia
[2]Computational Informatics CSIRO, ACT 2601, Australia

Keywords: collaboration, science art, visualisation, insects

ABSTRACT

Visualising the world of insects is at an exciting and innovative stage. New resources and technology allow exploration of intricate and complex detail at the miniscule scale of internal and external microscopic examination. In this project, a unique collaboration between a scientist and an artist has unified scientific and creative research interests in visualising insects from the Australian National Insect Collection. This intersection of science and art, within the fields of computational informatics, material science and entomology has proved a creative catalyst for imagination, ideas and innovation, particularly through the technical and aesthetic processes in which scientist and artist collaborate. In general, science art collaborations are conducted in order to create an artwork which has elements of science within the work. However, this project used art to illuminate the science for the purposes of research. We discuss the results of this science and art partnership, including the resultant challenges and benefits for a large interdisciplinary research organisation and for nationally exhibited artworks. This collaboration provides a model for mutually beneficial science/art explorations in related fields.

INTRODUCTION

"*Attack of the giant bugs*" and "*Scientists create supersized insects*" are two of many news headlines covering the 3D insects starring in the *Enlighten Canberra Festival* (ACT Government, 2013) and *Embracing Innovation Volume 3* (Craft ACT: Craft and Design Center, 2013). The insects appear in artworks as large-scale architectural projections on the Questacon building and in the form of 3D printed titanium. These works are the result of a unique collaboration between Science Art Fellow, Eleanor Gates-Stuart and research scientist, Dr Chuong Nguyen at the Division of Computational Informatics, CSIRO.

These works were a response to a mutual research interest in visualising insects and although the individual research had a different focus, the fusion of our ideas and the opportunity to make something new for public viewing led to some very interesting directions for the work produced at the CSIRO. The interest in making something new for public viewing had unforeseen consequences for the communication of science to CSIRO researchers themselves, through the medium of art. Unlike previous art-science collaborations which have led to the production of works of art with a science-based content, such as those of artists Sophie Munns (Munns, 2013) and Francesca Samsel (Samsel, 2012), this collaboration resulted in increased understanding of the structure of the insects from an entomological perspective and enhanced techniques for understanding their internal structure.

Amongst the many models for science communication, that of Stocklmayer (2013) provides for science communication between artists and scientists, and artists and the lay public. This model features three possible intended outcomes from such interactions – one-way information, knowledge sharing, and knowledge building (p.30). In the first case, the intended outcome is simply to inform, through presentation of science without structured provision for feedback and modification. The placement of art installations on the outside of public buildings might be considered to be in this category, since the *Enlighten* project was intended to interest and excite, but had no provision for specific feedback. This aspect of the project was, in many respects, similar to the works described by Wilson (2002) in his book about the intersections of science and art. Wilson describes the work of Herbert Duprat, for example, who creates strange hybrid objects through the metamorphic processes of insects. His art requires a detailed understanding of the insect's life cycle and behavior to create what are essentially 'sculptures'. Mark Thompson, on the other hand, has created installations based on bees, including live bees and their honeycombs He uses bees to demonstrate political points about crossing borders. (Wilson, 2002, pp116-117). In all these cases, the artist (who is very familiar with the underlying science) uses the science to create an art work. This is the most usual process resulting from the intersection of these disciplines, as is also exemplified in Korsmo (2004) concerning print and film media and Frankel (2001) concerning photography.

In Stocklmayer's(2013) third case, however, knowledge building is intended to "create new meaning or understanding from different knowledge systems" (p.30). This outcome is the major focus of this paper, since the art-science collaboration we describe was a sharing of two very disparate knowledge systems. The outcome was a fusion of knowledge, to create a product which could not have evolved using only one of these systems. Further, the outcome for the scientist was a critical outcome for the partnership.

In this paper, we therefore discuss how we came to develop and create these artworks, the influence on our own research directions, our collaborative results and interaction with other scientists at CSIRO. We argue that such science/art collaborations provide a valuable means to communicate science in an alternate and engaging way, enabling the research itself to be communicated to large audiences. This exposure differed from popular media, in that it reached large numbers of casual passers-by who observed the art covering the exterior walls of major national institutions. For the scientist, this method of communication enables articulation of the research in the public domain in a way that reaches people who do not seek to engage, as they might with a television documentary or a newspaper article. The point here is that the public installation was portraying Nguyen's research in an accessible way, rather than some aspect of science being appropriated for an artistic outcome. As Nguyen experienced, "Technical publications at conferences and scientific journals are the main channels for a scientist to communicate their works to their peers. Occasional press releases are the only means of communication with the public who support and benefit from such work. This is very limited effect, as it is produced by technical staff and is limited to research and technical communities. An artist can provide a very powerful alternative interpretation and publication channel for the science. The artist's interpretation of the science work provides new exposure that can benefit not only the individuals involved in creating the artworks but the host institution, in terms of the much wider audience and impact. It also benefits the viewing public in terms of enriching their experience and improving their knowledge of contemporary science.

Although this aspect was highly relevant, however, and was the initial drive for the collaboration, this paper mainly focuses on the importance of the collaboration and the communication to the scientists concerned.

CONTEXT

Figure. 1. Artwork, 'Jewels' by Eleanor Gates-Stuart

Gates-Stuart's residency as Science Art Fellow at the CSIRO was awarded as the successful recipient of the 2013 Centenary of Canberra's Science Art Commission. The CSIRO residency bridged the Divisions of Computational Informatics, the Food Futures Flagship and the Australian Plant Phenomics Facility.

In the CSIRO's rare books collection, Gates-Stuart discovered the beautiful book plate illustrations produced for 'The Insects of Australia' (Nanninga, 1991). What followed was a series of artworks developed (Gates-Stuart, 2012), such as 'Jewel', as shown in Figure 1, that respectfully pays homage to the different techniques of visualising insects. This compositional approach of embedding content, layering images and merging visual artifact demonstrates Gates-Stuart's method of representing and exploring scientific information. Her interest in automated technologies, particularly with plants became the nexus to meeting Nguyen (Cross, 2013a), whose postdoctoral research focuses on developing and implementing methods that are fundamental to the automated (or semi-automated) interpretation of multiple 2D images and 3D measurements of organisms, specifically plants and insects. Our mutual interest in 3D imagery sparked a partnership that proved to be a creative catalyst for science art ideas across CSRIO ((Gates-Stuart et al., 2013) and the beginning to our exploration of visualising insects, As Nguyen recalls, “We began by capturing 3D shapes and colours of insects in order to present them visually and artistically to the public, but the unexpected outcome was that the research itself was illuminated. The connection between the artist and the scientist and the initial results of beautiful insect models sparked a special collaboration between Gates-Stuart and Nguyen”.

Our first collaborative work, ‘*Intervisble’*, combined 3D models of both plants and insects and was devised as a concept to enable a public audience to compare human and insect vision through an interactive exhibition, as shown in Figure 2. The *‘Intervisible’* installation was designed to let the viewer experience images as if looking through the eyes of an insect whilst the insect eye (in this case a Kinect camera) is viewing the visitors and detecting human movement. Using specialised computer software, the images are then projected back into the interactive space on another screen, thus revealing to the visitor that the insect is also watching them. Although this concept did not proceed to final production, it did catalyse an important step in cross-divisional collaboration through the combined efforts of researchers and scientists across Computational Informatics, Information Management and Technology, Entomology, the Australian National Insect Collection, eResearch Visualisation and the Australian Plant Phenomics Facility. In the words of Nguyen, this collaboration enabled and encouraged: “a) a complementary role between science and art where science provides new materials for art to explore and art provides new interpretations (and publicity) for science; b) the thirst to explore new domains, that helps one learn as a scientist to better work with them, exploit their strengths and overcome their weaknesses); c) an approach to extending and strengthening new collaborations by removing possible friction due to human factors such as fear of sharing important information and unfair competition (CSIRO’s large breath of research makes it easier to go across multi domains, but this work was a special contribution to further counteract/neutralize these negative human factors.). This third point is a major one because it helps to cultivate healthy collaboration collaborations not only between the artist and the scientists, but also between the scientists themselves. As illustrated later in section “TITANIUM INSECTS”, scientists gain new meaningful links between their isolated research activities and can later form collaborations beyond original scope.”

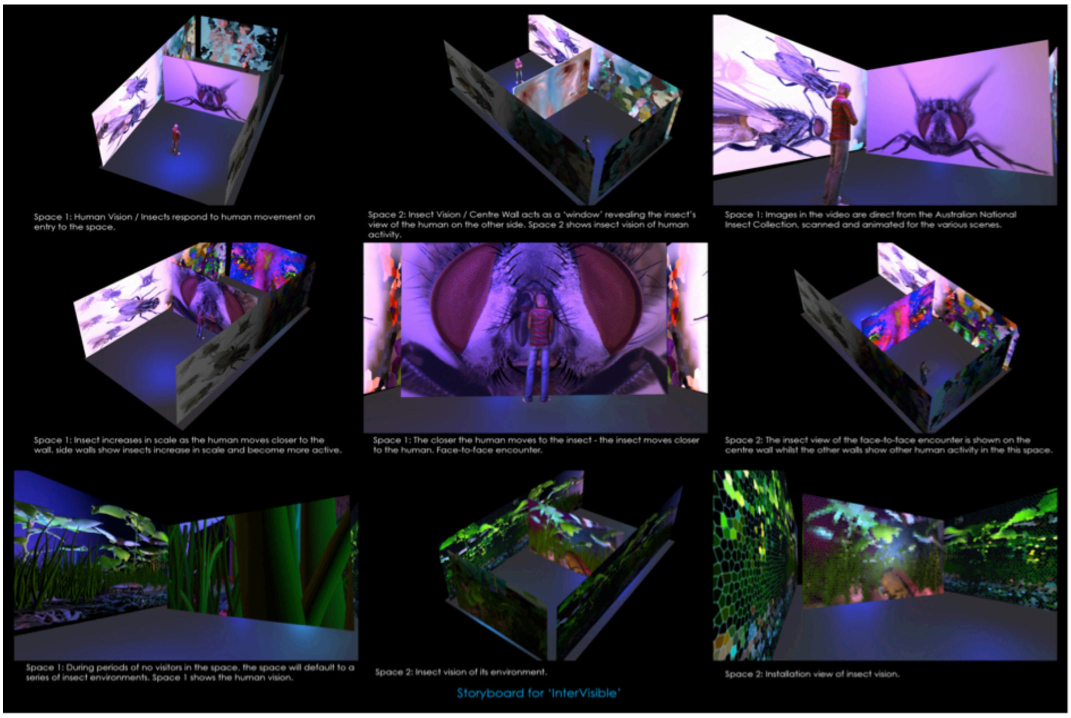

Figure. 2. 'Intervisible' Storyboard: Face to face encounters with an insect environment. Virtual Reconstruction of Insects from the Australian National Insect Collection and plants from the Australian Plant Phenomics Facility.

CREATING 3D MODELS

Insects are fascinating subjects and there has been a large number of creative works relating to them. Hand drawn illustrations and photographs of insects are common methods of capturing their shapes and colours. Creating 3D models of insects using 3D modeling software is another common modern method (König, 2009; Murakawa et al., 2006). Due to their small size, however, insects are difficult to scan to create a 3D digital copy. Attempts have been made to scan insects using laser scanners (David-Laserscanner, 2009; Mayrhofer, 2013) but the results have low resolution and have missing texture and colours. Laser scanning and image-based reconstruction methods have been used by Atsushi et al., (2011) to scan very small objects with some success, but the scanned objects are limited to simple geometries. Micro Computed Tomography has recently demonstrated high resolution 3D models of insects with internal structures (Metscher, 2009), but this method does not recover texture or colours of the object. This has proved a problem for the research, in that the interior structures of the insect cannot usefully be viewed while the external appearance plays a more important role..

The method we used to create 3D insect models for our work is somewhat similar to that of Atsushi et al. (2011) but the resulting 3D models have much higher resolution and higher structure complexity. Nguyen's system consists of a two-axis turntable, a DSLR camera with a macro lens, and a macro rail. The system can capture hundreds or thousands of multiple view images up to 21MP resolution. The macro rail is used to capture multiple focus images which are then combined into a single high quality in-focus image. 3D reconstruction software was used to automatically process multiple view images and create a 3D colorful model. Fig. 3 summarises this process of 3D reconstruction.

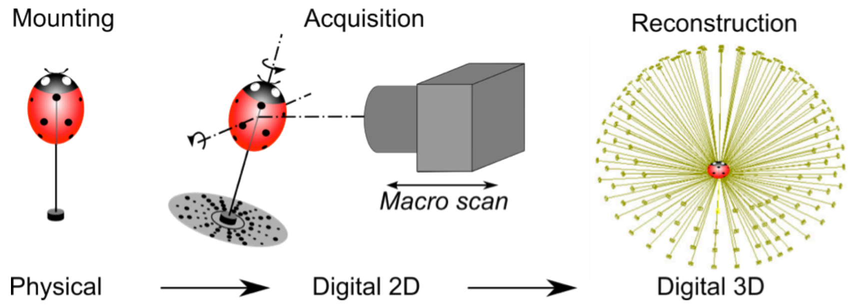

Figure. 3. Method of creating 3D models of insects

This research increased our interest in producing insects for large-scale formats, setting a challenge to retain high-resolution detail of insects during 2D to 3D reconstruction. Nguyen's approach to scanning insects involved complex technical solutions, not only with hardware but in the preservation of insects during scanning as well. Figures 4 and 5 show our own use of the insect images.

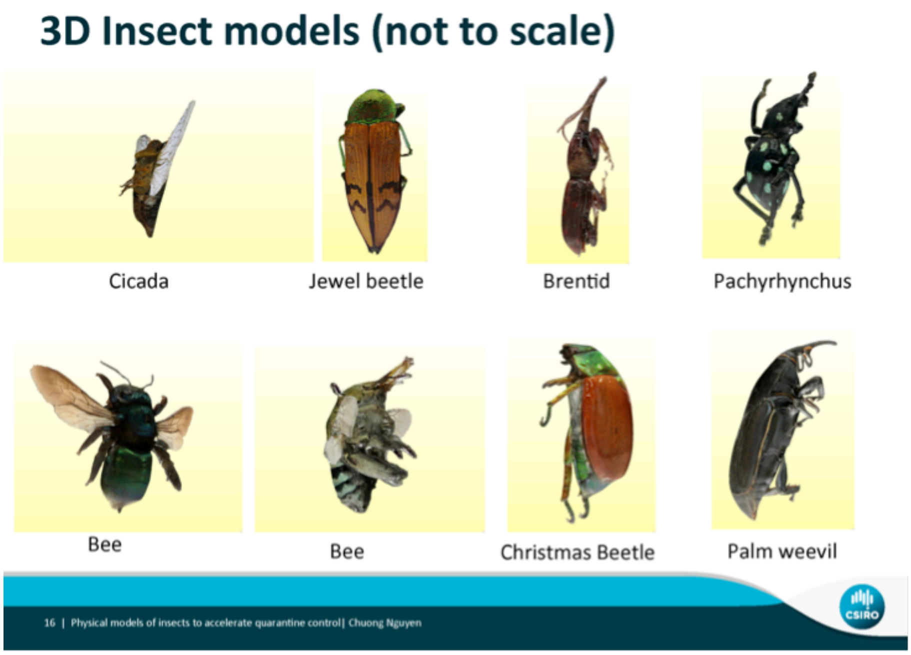

Figure. 4. Nguyen's 3D models of insects

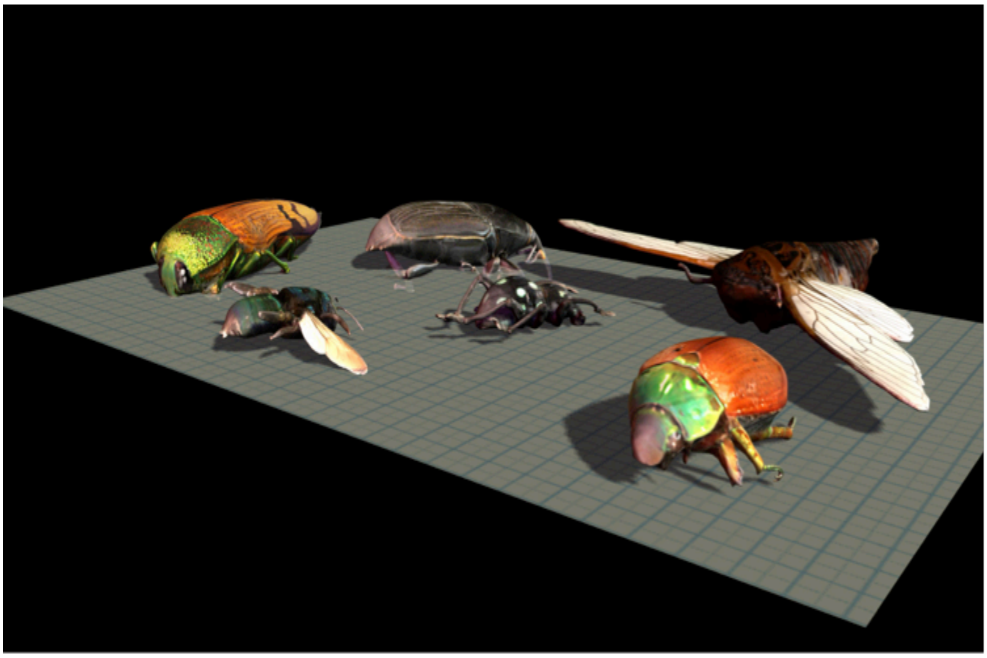

Figure. 5. Gates-Stuart's virtual reconstruction of 3D insects remodelled using animation software

ART INSTALLATIONS & AUDIENCE RESPONSES

The opportunity to test 3D scanning of insects from the Australian National Insect Collection and use volumetric data from the Australian Plant Phenomics Facility was the catalyst in the creation of the *Bugs* and *Grassland* series, both of which were remodelled and transformed as architectural projections for Canberra's *Enlighten* public art event. The manipulation of 3D models and images transformed the insects into a new visual dimension, merging the intricate texture mapping of Nguyen's meshes and reworked through 3D animation software which enabled the insects to "come alive".

Working effectively with scientists from different technical backgrounds was very challenging for both partners and required particular technical skills. For Gates-Stuart, maintaining a lab notebook helped her to think and work like a scientist. Reading scientific journal papers and asking technical questions to make sense of scientists' work is another crucial skill. This deep understanding of the research enabled the development of the meanings behind several artworks, including the one in Figure 1.

To push this collaboration and related collaborations to the highest level, strategies were developed to deal with negative factors that hindered genuine collaboration efforts. CSIRO, with its wide breath of research domains, provides an ideal environment for multidisciplinary collaboration. Nevertheless additional efforts were required to maintain mutual trust and ownership of the project; these included due acknowledgement of contributions, sharing of information, and development of mutual care and regard.

An opportunity to preview a live screening of the 3D insects had been presented earlier in the year at *Spectra, Conference of Art and Science* (Kennedy, 2012) which showed the insects crawling around the CSIRO Entomology building (Gates-Stuart, 2013). In this instance, the groups of insects were placed on a flat, vertical, visual plane that rotated horizontally through 90° until the plane became a single line, at which point, the insects fell from one space into another. Influenced by Flatland (Abbott, 1992) and the n^{th} dimension character of images, the aim was to create the illusion of the crawling bugs suddenly disappearing, having flipped their spatial position through the line and disappeared into black space. Actually, there was no real black space but, an illusion was created of the bugs having dispersed into the building.

An eerie aspect of this installation was the illusion of bugs finding spaces to hide, in what seemed a familiar scenario for the public to recognise occurring in their home environment. It was interesting watching the audience twitch and scratch at themselves at the sight of the large scale insects. This included the sound of nervous laughter, as most people are wary of certain insects (Weinstein, 1994) and many comments related to the realism of the 3D bugs.

Figure. 6. Rendered Image: 3D 'Bugs' walking the line

In *Enlighten*, the approach was modified because moving images were not an option for the event. As a result, we placed an emphasis on the insect's body mapping the intricacy of their tactile bodies, detailing their shape and body markings across the surface of the building. The insects were enriched in colour and dense in visual information. The artworks were architecturally mapped and projected onto the Questacon building by *Electric Canvas* and gained wide media attention.

Reports emerged of giant bugs spotted in the parliamentary triangle area of Canberra crawling over the Questacon building (McKay, 2013) and media teasers included, “Does the thought of giant bugs crawling over Canberra’s National Institutions frighten or fascinate you?” (Kimball, 2013). Media interest in the insect artworks was evident: they were the only one of the five “Enlighten” installations on the Questacon building which featured these animals. The CSIRO Facebook album, *Enlighten Canberra Festival*, received the most ‘likes’ for the month of March (CSIRO, 2013), an interesting statistic given the range of exciting science news on CSIRO’s social pages for that month. Internally, our science art collaboration reached the division’s newsletter (Cross, 2013b) and caught the attention of the Chief Executive (Cooper, 2013), an important factor in raising cultural awareness of communicating science initiatives within the organisation.

Figure. 7. Insect surface and mapping designs shown with the images of 3D models projected onto the Questacon Building.

TITANIUM INSECTS

This synergy between us, scientist and artist, enveloped other collaborators at CSIRO as we developed the opportunity to enhance other research areas. Linked with Nguyen's expertise in capturing, assembling and interpreting data, we met with Zimmerman Fellow in Weevil Research, Dr Rolf Oberprieler, to discuss this species in more detail and to have the opportunity to bring the insect into the public domain.

Our first attempt to achieve a low-cost alternative to Computed Tomography (CT) scanning by digitally reassembling thin 2D sections obtained via microtome. It was unsuccessful as the tough tank like bodies of the *Sitophilus granarius* specimens tended to explode during sectioning. We were aware that successful reconstruction of the internal structures of weevils is also of scientific interest because the internal genitalia are a key discriminative character between species (Honnicke et al., 2010), and it soon became clear that we would need the help of Dr Sherry Mayo, Senior Research Scientist in CSIRO's X-ray and Synchrotron Science and Instruments team. At the Australian Synchrotron, Mayo scanned a weevil and produced an excellent 3D model insect using *Drishti.* This free open source software was developed by the Australian National University for 3D visualization of CT Data.

At 3-5mm long, the weevil easily became a motivation for the optical 3D model capture system that Nguyen was to later develop. However, at this time, and following the success of the architectural projections, we were approached to be part of the *Embracing Innovation Vol. 3* exhibition. This was a great opportunity to produce 3D models in titanium, given the strength and tough exterior we had attributed to the weevil body and this unique method of showcasing the insects with innovative 3D printing technology.

A discussion with Theme Leader, Dr John Barnes, in CSIRO Titanium Technologies, led to an exciting collaboration involving entomology, synchrotron science, computer vision, 3D reconstruction and 3D printing in titanium. This in turn created an interdisciplinary team across divisions. Our challenges ranged from retaining insect detail in the printing without over-simplifying mesh structures, authentic scaling of the insect relative to the printed size and real-life, the quality of surface structure through the printing process and its final finish. Aesthetic judgments balanced between the concept of an insect and the realism of the insect. For instance, if "art can be anything that you can get away with" (McLuhan, 1967) would this affect the communication of the science? In this case, the technologies and methods intrinsic to making the insects are important to communicate. These messages are visibly evident in the final result, as they might be in the viewer's experiences and encounters with the actual insects.

Figure. 8. 3D wire frame beetle model (left) and titanium prototype (right)

The initial titanium prototypes resembled a fossil appearance (see Fig. 8) and were almost grub-like with distorted features. It was only when the titanium bugs were moved under illumination that the jewel-like quality of their surfaces revealed itself and the magical iridescent effect, reminiscent of, but different from the micro and nanostructures found in real insects, became apparent. Once we rescaled the mesh to suitable sizes for printing, the first batch of insects was produced using four insect models replicating the following beetles: Christmas Beetle (*Scarabaeidae: Rutelinae*), LongHorn Beetle (*Cerambycidae*), Weevil (*Gagatophorus draco)* and the Wheat Weevil (*Sitophilus granarius*). Three of the insects were anodised to give colour and to group each set of species.

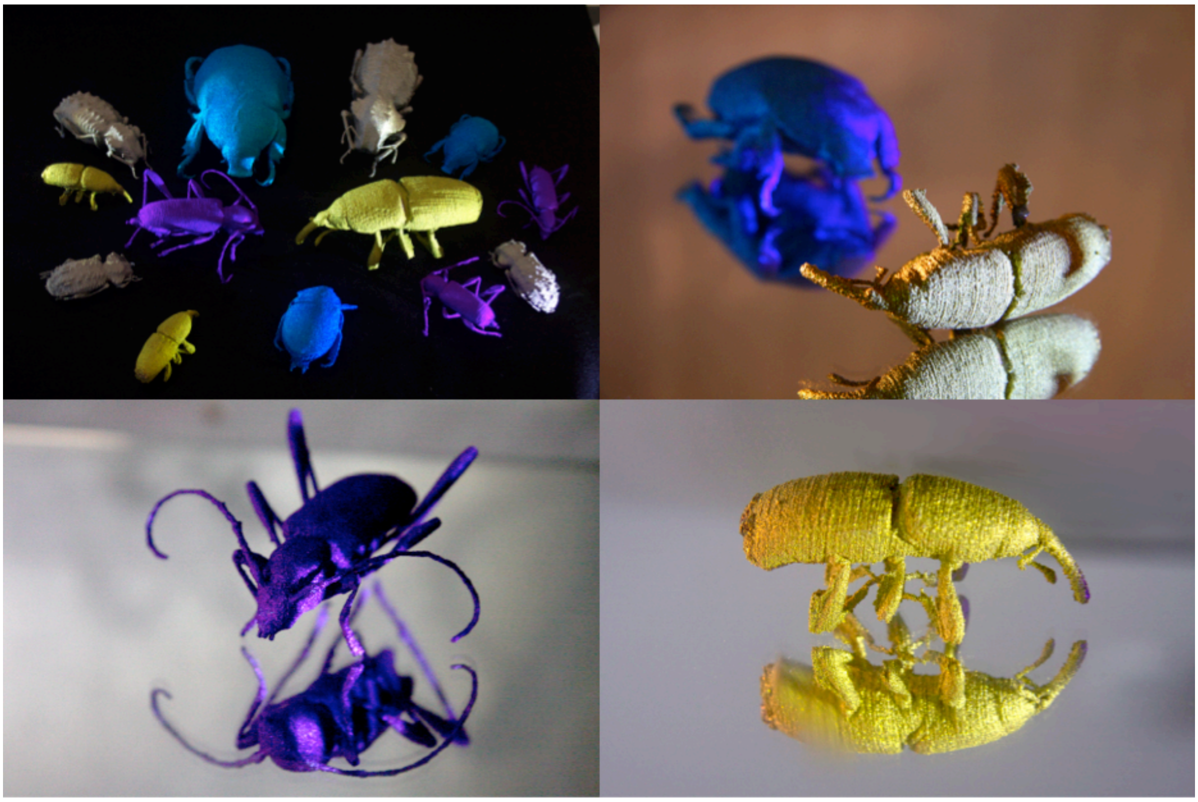

Figure. 9. 3D Titanium insects

CONCLUSION: COMMUNICATION OUTCOMES

The *Enlighten Canberra* event attracted over 115,000 contributing to the Gross Territory Product (GTP) an estimated $1 million (Barr, 2013; Events ACT, 2013). As with the *Bugs on Buildings*, this collaboration generated considerable publicity which, in turn has led to further enquiries about the underlying research and methods. From the perspective of a multidisciplinary science organisation, however, one of the key benefits of the science/art collaboration process has been to make connections and communications between researchers from disparate fields: entomology, computer vision, tomography and materials science. In the words of the scientist, Nyugen comments, "We found that Science and Art greatly complement each other. By pushing this win-win synergy to its highest level, the collaboration led to spectacular outcomes beyond what could possibly be achieved from individual domains. The complementary roles between Science and Art in this project enabled a special approach for an artist to work successfully with scientists across multi technically sophisticated backgrounds, and a special approach to extend and strengthen new collaborations between artist and scientists and between scientists themselves by removing existing barriers originating from human and organizational factors".

This project was unique in its extensive collaborative reach across the organisation, clearly with multifaceted value and opportunity for all involved.

Beneficial outcomes for the organization have been wide media exposure and public attention. New audiences have been reached through those who attended the Enlighten evenings on the lakefront. Promotion via the Australian Broadcasting Corporation (ABC) helped to increase audience as ABC3 Behind the News (Davis, 2013) attracted over 500,000 viewers and local ABC 7.30 Report (Kimball, 2013) with 52,000 viewers. The CSIRO's support and resources given to the project, particularly in its promotion through CSIRO social media and science communicator's reports (A. Beggs, 2013; Cross, 2013c; Long, 2013; McKay, 2013) led to national and international press attention, electronic and broadsheet copy. The internal value of the CSIRO communication was equally important as it facilitated wider participation for collaborative projects, positive feedback to divisional unit support, new co-authored publications and research credit to the scientists.

Following the success of the titanium insects, Nguyen's research has received more attention. He has been encouraged by CSIRO to further develop his optical 3D model capture system for better quality of smaller insects such as wheat weevil. Nguyen also found opportunities to expand the applications of 3D insect modeling to quarantine control. This has caught the attention of the Department of Agriculture in applications that on-site quarantine officers can use, 3D models of known pests on a mobile enable decisions about whether a bug is harmful. 3D pest models help them make more accurate decision than photographs.

Figure. 10. Nguyen: Better quality of smaller insects for biosecurity

For the artist, the benefits of working in science are evident, from the depth and insight to her practice and the open interaction her artworks generated in opinion and feedback from both scientist and the general public. This exchange of communication provided a valuable pipeline in the collaboration process and feedback to the CSIRO, particularly in response to making informative decisions and practical application of the work. Production quality and aesthetic judgments were balanced with research challenges in finding technical solutions and the need for advancing science knowledge. This collaboration thus proved to be of equal benefit to both scientist and the artist, a successful interdisciplinary relationship that promotes a positive value of having artists as integral team members in science organisations.

In conclusion, the aspects of this collaboration that we offer for a model of mutually beneficial science/art explorations in related fields are:

1. New ways to portray scientific research
2. Opportunities for cross-disciplinary science research and communication
3. Opportunities for the institute itself to extend its public outreach in non-traditional ways
4. Opportunities for publishing research in a wider range of journals
5. Exhibit of artwork in non-traditional venues, e.g. science museums.

ACKNOWLEDGEMENT

Eleanor Gates-Stuart's residency has been supported through the Transformational Biology initiative and in association with CSIRO's Future Grains Theme. Chuong Nguyen's fellowship has been supported by CSIRO's Office of the Chief Executive Science and Transformational Biology Platform. We gratefully acknowledge all those who have contributed to, or collaborated with the works described in this paper, including CSIRO's Lab 22 and the Australian National Insect Collection. We would also like to thank Professor Sue Stocklmayer, Australian National Centre for the Public Awareness of Science, ANU, for her generous support and advice with this paper.

REFERENCES

A. Beggs. (2013). Giant 3D printed bugs shed light on insect anatomy. *CSIRO*. CSIRO. Retrieved from http://www.csiro.au/Portals/Media/Giant-3D-printed-bugs-shed-light-on-insect-anatomy.aspx

Abbott, E. A. (1992). *Flatland: a romance of many dimensions*. Dover Publications, New York.

ACT Government. (2013). Architectural Projections | Enlighten. Retrieved from http://enlightencanberra.com.au/event-info/architectural-projections/

Atsushi, K., Sueyasu, H., Funayama, Y., & Maekawa, T. (2011). System for reconstruction of three-dimensional micro objects from multiple photographic images. *Computer-Aided Design*, *43*(8), 1045–1055. Retrieved from http://www.sciencedirect.com/science/article/pii/S0010448511000327

Barr, A. (2013). Barr declares Enlighten Victory. *Riotact*. The RiotACT. Retrieved from http://the-riotact.com/barr-declares-enlighten-victory/105032

C. Kennedy. (2013a). Artists. *CSIRO*. CSIRO. Retrieved from http://www.csiro.au/Portals/Education/Programs/SCIENCE-ART/Artists.aspx

C. Kennedy. (2013b). CSIRO and the arts. *CSIRO.au*. CSIRO. Retrieved from http://www.csiro.au/en/Portals/Education/Programs/SCIENCE-ART/CSIRO-and-the-arts.aspx

Cooper, J. (2013, March). Megan Clark's visit. CSIRO.

Craft ACT: Craft and Design Center. (2013, September 26). Embracing Innovation. GeniusMoon. Retrieved October 31, 2013, from https://www.craftact.org.au/projects/embracinginnovation/

Cross, A. (2013a). Dr Chuong Nguyen: creating 3D models from 2D images. Retrieved October 30, 2013, from http://www.csiro.au/chuong-nguyen

Cross, A. (2013b). Eleanor and Chuong on TV. *MIScellanea 54*. CSIRO.

Cross, A. (2013c). Art and science cross-pollinate | News @ CSIRO on WordPress.com. *news@CSIRO*. CSIRO. Retrieved from http://csironewsblog.com/2013/08/16/art-and-science-cross-pollinate/

CSIRO. (2013). *Social Media Report: March 2013*. Retrieved from https://teams.csiro.au/sites/commsnetwork/corpcomm/Social media stats/Social media stats 2013/March 13 social report.pdf

DAVID-Laserscanner. (2009). DAVID-Laserscanner Forum • View topic - David vs NextEngine. *DAVID-Laserscanner Forum*. Retrieved November 06, 2013, from http://forum.david-3d.com/viewtopic.php?p=7163

Davis, E. (2013). 3D Creepy Crawley Bugs: Behind the News. ABC Behind the News. Retrieved from http://mpegmedia.abc.net.au/abc3/news/BXN_3DBugs.mp4

Events ACT. (2013). Enlighten 2013 - Key Findings. *Events ACT, Economic Development*. Australian Capital Territory, Canberra. Retrieved November 06, 2013, from http://enlightencanberra.com.au/Attachment-A-Enlighten-Key-Findings-2013-.pdf

Frankel, F. (2001). Communicating science through photography. *Journal of Chemical Education, 78*, p.1312.

Gates-Stuart, E. (2013). *Bugs Crawling over Entomological Building at CSIRO on Vimeo*. Vimeo. Retrieved from https://vimeo.com/50977557

Gates-Stuart, Eleanor. (2012). 20×20. *eleanorgatestuart on WordPress.com*. Retrieved from http://eleanorgatestuart.com/insects/20x20/

Gates-Stuart, Eleanor, & Clark, M. (2012). Iridescent Ray. Retrieved from http://stellrscope.com/other/iridescent-ray/

Gates-Stuart, Eleanor, Nguyen, C., Adcock, M., Bradley, J., Morell, M., & Lovell, D. R. (2013). Art and Science as Creative Catalysts. In *IEEE VIS 2013 AP* (p. 8). IEEE VIS2013 AP. Retrieved from http://visap2013.sista.arizona.edu/papers/Stuart_CreativeCatalysts.pdf

Honnicke, M. G., Cusatis, C., Rigon, L., R-H, M., Arfelli, F., Foerster, L. A., & Rosado-Neto, G. H. (2010). External and internal structure of weevils (Insecta: Cleoptera) investigated with phase-contrast X-ray imaging. *Nuclear Instruments and Methods in Physics Research A*.

Kennedy, C. (2012). Spectra | Symposium of Art and Science. Retrieved October 30, 2013, from http://www.spectra2012.com/

Kimball, C. (2013, March 1). 7.30 Report: Canberra is Enlightened. Australia: The Australian Broadcasting Corporation (ABC). Retrieved from http://www.abc.net.au/news/2013-03-01/canberra-is-enlightened/4548714

König, S. (2009). “Fly” - Timelapse Modeling in Blender / Part 01. Retrieved November 06, 2013, from http://www.youtube.com/watch?v=fGyr9vfh19w

Korsmo, F.L. (2004). Shaping up Planet Earth. *Science Communication, 26*, 162-187.

Long, J. (2013). The Helix. *The Helix: Science with a Twist*, (151), Cover, Pages 12–15.

Mayrhofer, B. (2013). 3D Scan and 3D Print “The Fly” with VirtuZoom. *DIY3dscan*. Retrieved November 06, 2013, from http://www.diy3dscan.com/viewtopic.php?f=42&t=92

McKay, C. (2013). Insect of the week: attack of the giant bugs | News @ CSIRO. *CSIRO*. CSIRO. Retrieved November 06, 2013, from http://csironewsblog.com/2013/03/07/insect-of-the-week-attack-of-the-giant-bugs/

McLuhan, M. (1967). *The Medium is the Message*. Gingo Press Inc.

Metscher, B. D. (2009). MicroCT for comparative morphology: simple staining methods allow high-contrast 3D imaging of diverse non-mineralized animal tissues. *BMC physiology*, *9*(1), 11. doi:10.1186/1472-6793-9-11

Munns, S. (2013). homage to the seed weblog . . . *Seed Art Lab*. Retrieved from http://sophiemunns2010.blogspot.com.au/

Murakawa, J., Yoon, I., Hong, T., & Lank, E. (2006). Parts, image, and sketch based 3D modeling method, 67–74. doi:10.2312/SBM/SBM06/067-074

Nanninga, F. (1991). *The insects of Australia : a textbook for students and research workers* (2nd Editio., p. full–colour plates 1 to 8). Melbourne University Press, Carlton, Victoria. Retrieved from https://data.csiro.au/dap/landingpage?pid=csiro:4761

Samsel. (2012). Sci Vis Collaborations. *Francesca Samsel Website*. Retrieved from http://francescasamsel.com/home_html/Sci_Vis_Collaborations.html

Stocklmayer, S. M. (2013). Engagement with science: Models of Science Communication. In J.K.Gilbert & S.M. Stocklmayer (Eds.), *Communication and engagement with science and technology: Issues and dilemmas.* (pp. 19–38). NY: Routledge.

Weinstein, P. (1994). Insects in Psychiatry. *Cultural Entomology Digest*, (2). Retrieved from http://www.insects.org/ced2/insects_psych.html

Wilson, S. (2002). *Information Arts: Intersections of Art, Science and Technology.* Cambridge: Leonardo.