Institution: Manchester Metropolitan University

Unit of Assessment: B11 Computer Science and Informatics

Title of case study: Synthetic Biology and Citizen Science

1. Summary of the impact

This case study is based on research at the interface of computer science and biology, undertaken at MMU. Subsequent inter-disciplinary work was partly supported by the EPSRC Bridging the Gaps: NanoInfoBio project, and led to the creation of a new "citizen science" organization, which is now one of the leading groups of its type in the world. The specific impacts are (1) generation of revenue for a new business operation created as a result of the project, (2) the stimulation of and influence on policy debate, and (3) the stimulation of public interest and engagement in science and engineering.

2. Underpinning research

Members of the Novel Computation Group (School of Computing, Mathematics and Digital Technology, MMU) study alternatives to "traditional" forms of computing, including new theoretical models and non-silicon physical substrates **[1]**. This often requires an inherently inter-disciplinary approach. One well-established research theme is *synthetic biology*: the application of engineering principles to the (re)design of living biological systems. The Group leader, Prof. Amos, is a world-leading researcher in the field of molecular computing; his 1997 Ph.D. thesis was the first in the field of DNA computation. In 2006, Amos published a book **[2]** describing this emerging field of biological computation; a review in *Nature* (March 15 2007, p. 263-264) stated that "This is an enjoyable book… I recommend it to anyone interested in computation writ large who is not afraid to cross disciplinary boundaries that once seem impassable." Amos contributed to a paper published around the same time, which called for closer links to be established between computer science, engineering and the life sciences in order to fulfill the true potential of bio-inspired computing **[3]**. To help further develop such links, two projects were funded at MMU from 2009 onwards. The Bridging the Gaps: NanoInfoBio (NIB) project at MMU was funded by the EPSRC in 2009 (EP/H000291/1, £289,095), and ran for 30 months **[4]**. The core aim of the project was to bring together researchers from different disciplines to focus on problems at the intersection of nanotechnology, informatics and biology. In total, the project supported 21 different projects, with funding ranging from small student bursaries to £25K grants. BACTOCOM was a European Commission Collaborative Project (248919, €1,949,997, 2010-2013) to investigate the creation of an "evolvable" synthetic biology platform **[1]**. Amos was the PI on both grants, and, together, they led to a significant increase in the amount of work at the intersection of biology and computer science, both at MMU and beyond.

The original NIB proposal stated "An important aspect of the programme's activities will be public engagement", and public outreach was assigned a specific work package task within BACTOCOM. One of the public engagement events we organized was a panel discussion on synthetic biology, which was attended by Asa Calow, a Director of the Manchester Digital Laboratory (MadLab). MadLab is an independent open learning and experimentation environment, and Calow suggested that we collaborate to develop a "DIY bio" laboratory space in Manchester. This meeting was a *direct result* of the public engagement event, as there had been no prior contact. The resulting proposal was funded by the Wellcome Trust's People Awards scheme (WT095313MA, £29,705), creating the DIYbio Manchester (DIYBIOMCR) project **[5]**. "Do-it-yourself" biology (DIYbio) is a growing international movement, the aim of which is to democratise and widen access to biotechnology (which, of course, is of direct relevance to synthetic biology). The fundamental philosophy of DIYbio is to bring together interested "amateurs' with professional scientists, with the aim of stimulating discussion, widening public understanding, and ensuring the safe and ethical management of amateur experiments. With this project, we aimed to engage the public with underpinning research in the unit, as well as with the full range of new ideas and societal issues at the bio/info interface. When it was set up, DIYBIOMCR was only the second such group in the UK, and one of only a handful worldwide. The creation of this organization (and its resulting impact) can therefore be traced directly back (and attributed) to the NIB project, which, in turn, arose as a result of research in the unit taking place at the intersection of computer science and biology.

Key Staff:

Prof. Martyn Amos, Chair of Novel Computation; appointed SL, 2006; Reader 2010; Professor 2012.

3. References to the research

[1] Goñi-Moreno, A., Amos, M. & de la Cruz, F. (2013) Multicellular computing using conjugation for wiring. *PLOS ONE* **8**(6), e65986. (Recent exemplar output of the BACTOCOM project.) doi: 10.1371/journal.pone.0065986 **(1 Google Scholar citation)**.

[2] Amos, M. (2006) *Genesis Machines: The New Science of Biocomputing*. Published November 16 2006, ISBN 1843542242. Atlantic Books, London. Full details and list of reviews at http://www2.docm.mmu.ac.uk/STAFF/M.Amos/gm.html. *Nature* review at http://www.scribd.com/doc/12922/Biological-programming (**23 citations for the book**).

[3] Timmis, J., Amos, M., Banzhaf, W. & Tyrrell, A. (2006) "Going back to our roots": Second generation biocomputing. *International Journal of Unconventional Computing* **2**:4, p.p. 349-378. (**20 citations**)

[4] Jacobs, N. & Amos, M. (2012) NanoInfoBio: A case-study in interdisciplinary research. In Kettunen, J., Hyrkkanen, U. & Lehto, A. (Eds.) *Applied Research and Professional Education*, p.p. 289-309. Turku University of Applied Sciences. Available at http://arxiv.org/abs/1211.5508. (An earlier version of this paper, made available in 2010 as an Arxiv pre-print, has **5 citations**).

[5] Amos, M., Calow, A., Jacobs, N., Jung, H.Y., Linton, T. & Verran, J. (2012) Manchester DIYbio. In Bowater, L. & Yeoman, K., *Science Communication: A Practical Guide for Scientists*, p.p. 250-251, Wiley-Blackwell.

Grants

Funder	Project	Value to MMU	Dates	PI
EPSRC	Bridging the Gaps: NanoInfoBio	£289,095, plus additional £50K from EPSRC. Total: £339,095	Sept. 2009-Nov. 2011	Martyn Amos
European Commission	BACTOCOM: Bacterial Computing with Engineering Populations	€328,426 (Grant total €1,949,997).	Feb. 2010-Jul. 2013	Martyn Amos
Wellcome Trust	DIYbio Manchester	£29,705	Mar. 2011-May 2012	Martyn Amos

4. Details of the impact

NIB directly led to the creation of an *entirely new organisation*. DIYBIO Manchester (DIYBIOMCR) is now an established independent entity, the UK's largest "do it yourself" biology group, and is an active participant in the global DIYbio movement. For a full list of relevant DIYBIOMCR activities, please see **[A,B]**. Relevant projects included the Manchester Microbe Map (a bacterial "atlas" of bus stops in Manchester), and the construction of "homebrew" DNA replication equipment.
As a result of the project, the turnover of MadLab (the parent organization) has grown *significantly*,

and, since 2011, an average of 80% of MadLab's income has been due to DIYBIOMCR. The MadLab finance manager, provided the following figures on 14/11/13:

Period	Total Income	DIYBIO-attributable	Unrelated to DIYBIO	DIYBIO-attributable %
2013-14 (pred.)	£330,000	**£228,000**	£102,000	**69**
2012-13	£160,606	**£140,919**	£19,687	**88**
2011-12	£85,185	**£72,011**	£13,174	**85**

These show income that is *directly attributable* to the DIYBIOMCR project, including income from the Wellcome Trust, consultancies, residencies, paid workshops and other collaborative projects that arose as a result of the work done on DIYBIOMCR.

A deposition from MadLab Director states that "DIYBIOMCR has brought much positive attention to MadLab, and exposed the organization to a wide range of new audiences. We have become much more outward-facing, as opposed to focusing on community groups and in-house training. At the time, the Wellcome Trust funding was MadLab's largest single block of external money, and represented its most significant external relationship with another organization. This seed-corn money, in turn, gave access to more funding, and allowed MadLab to present itself in a different light to external bodies. To put it bluntly, the Wellcome Trust "seal of approval" gave MadLab a significant "cachet", on which we have since built. MadLab is now in the process of converting into a Community Interest Company, and we have separately raised £160K of the £250K we need to refurbish our space. Much of the money raised has come from local and national sources that have been developed and nurtured as a direct result of DIYBIOMCR." **[C]**

In recent years the US Federal Bureau of Investigation (FBI) has developed a DIY bio program that aims to share information and make connections between amateur scientists and local law enforcement officers. The objective is to address any concerns (on either side of the regulatory "fence"), and to provide a framework for ongoing discussions. The Bureau's local Weapons of Mass Destruction (WMD) coordinators are the focal point of such conversations, and ensure that local authorities (e.g., fire and police service, environmental health) are informed of the nature and location of cooperating DIY biology laboratories. The FBI also works closely with the Department of State on biosecurity, and the Department of Health and Human services on biosafety.

As a result of our high-profile activities, the FBI invited DIYBIOMCR participants Asa Calow and Rachel Turner to attend a workshop held in San Francisco on 12-14/6/2012; Calow and Turner were the only UK-based participants in attendance, and they were specifically invited as a direct consequence of the outcomes of DIYBIOMCR. The purpose of the workshop was to "educate the FBI about biology" (in the context of the growing DIY biology movement), and to "foster the positive relationship among FBI, DIYbio, amateur biology and local stakeholder communities to ensure safe conduct in science." **[D]** The FBI explicitly stated that "we want to model this *for the international community*..." (that is, they want to help to develop *policy* and *practice*, both within the US and beyond). Their explicit aim is to help to avoid extra regulation of DIYbio scientists "that hinders their abilities to push scientific progress. Ultimately, it will be up to the communities themselves how they wish to operate, and the FBI will continue to work with them to further their efforts." **[D].**

A subsequent email (27/7/2012) to Calow and Turner from an FBI supervisory special agent with the FBI Weapons of Mass Destruction (WMD) Directorate in Washington DC stated that "I wanted to thank you again for agreeing to come and present at the event ... Your perspective on media issues was delivered so well that I believe that a great impact was left [on] the attendees ... It really left a great impression on me that some direction and reinforcement is being given to this community in proactively engaging the media, to their ultimate benefit." **[D]**

A later message (10/6/2013) to Prof. Amos from the FBI Special Agent (about the DIYBIOMCR contribution) stated that "their insight, engagement within their community and energy makes them, in my eyes, a leader in being a proactive member of the amateur biology community… These steps take a long time to climb, but it seems as if they have been very successful in

developing a working model that serves their community. Additionally, Rachel's input regarding interactions with the media have kept this issue in high standing for our future events with this community." **[D]**

The total immediate (in-person) audience reached was around 700 for DIYBIOMCR [**B].** Results were disseminated widely, and though high-profile channels such as pieces (both 28/3/2012) on the main BBC Ten-o-clock News (estimated viewing figure: 4.75M) and Radio 4's *Today* programme (average weekly audience of around 7M**) [E,F]**.

5. Sources to corroborate the impact

All public sources are linked from http://www.scmdt.mmu.ac.uk/cir/REF

[A] DIYBIOMCR activities (during and after the grant):

Full list of projects/activities at http://www.scmdt.mmu.ac.uk/cir/REF

Manchester Microbe Map online at http://www.danhett.com/projects/microbe/.

Nature SpotOn blog article on DIYBIOMCR at http://www.nature.com/spoton/2012/12/spoton-nyc-diy-science-manchester-digital-laboratory-madlab/.

Wellcome Trust Public Engagement Adviser and DIYBIOMCR contact (details uploaded into the REF submission system)

[B] DIYBIOMCR evaluation:

Final Evaluation Report, Sally Fort. Available at https://dl.dropboxusercontent.com/u/3105497/DIYBioMcrEvaluationReport.pdf.

[C] Impact of DIYbio on MadLab organization:

Deposition from Director, MadLab (full details uploaded into the submission system).

[D] FBI/DIYBIOMCR consultation:

Information on FBI workshop available from link at top. Emails from FBI Special Agent (full details uploaded into the REF submission system) (27/6/12 and 10/6/13), plus *Guardian Northerner* blog article, 18/6/12 at http://bit.ly/189MVcQ

[E] Media coverage (TV):

28/3/2012: DIYBIOMCR featured on *BBC Ten O'Clock News*; write-up available at BBC Online at http://www.bbc.co.uk/news/science-environment-17511710. Viewing figures for BBC1 from www.barb.co.uk for week ending April 1 2012.

[F] Media coverage (radio):

28/3/2012: DIYBIOMCR featured on *BBC Radio 4 Today Programme*. Recording available at http://news.bbc.co.uk/today/hi/today/newsid_9709000/9709494.stm. *Today* programme figures from http://www.guardian.co.uk/media/2012/feb/02/radio-4-today-audience-figures-boost.