



DIGITAL TECHNOLOGIES,

Education and Creativity

An International Specialised Skills Institute Fellowship.

DR GREG GIANNIS

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i. Executive Summary

This Fellowship Report, being one outcome of Greg Giannis' research, identifies a gap in local knowledge; that being the delivery of software writing and digital hardware construction skills to creative industry students. The Fellow provides a rationale for the importance of addressing this gap, outlines the research undertaken to investigate how to best address this gap and concludes with recommendations and actions undertaken thus far.

The industry sectors targeted are the creative industries and the education sectors. The creative industries include professions such as artists, designers, musicians, game developers and media producers. The education sector includes community learning centers, primary, secondary, TAFE and tertiary, government and non-government education providers.

The Fellow's identification of skills enhancements required was validated by the knowledge gained from the Fellowship. This 'gap' was prevalent not only in Australia, but in many other locations around the world and is being subsequently addressed at a governmental level, targeting not only creative industries students but students in general. The Fellow's research dovetailed with a surge in international interest in 'coding' and STEM (Science, Technology, Engineering and Mathematics). Governments are attempting to address shortages in various industries by encouraging initiatives and setting new curriculums. This has led to the Fellow having greater engagement with the education sector, as the skills initially proposed for creative industries students are applicable to all students from primary through to secondary and tertiary.

The Fellow travelled to many centers of excellence, interviewed exemplars in the field and discussed the issues addressed in the report with many educators and arts practitioners.

In Brazil, the Fellow interviewed many educators and members of community initiatives. The educator that the Fellow had planned to meet, the only member of the Software Studies consortium that responded and agreed to meet, was unavailable at the last minute. Fortunately, the Fellow was able to call upon an associate who had curated an exhibition the Fellow was part of in 2009, and through this contact, conducted many more interviews than had been planned. The highlight of these interviews was the realisation of the efficacy of makerspaces as a means of disseminating knowledge to communities, as a place for the promotion of digital citizenship and civic engagement, within and outside of formal educational institutes.

Following Brazil, the Fellow travelled to the US. Here the Fellow interviewed educators, artists and students from UCLA. He interviewed and was given a tour by a lead educator at the Exploratorium in San Francisco. Spent many days interviewing staff and visiting makerspaces at the Creativity Lab, Indiana University. He interviewed teachers and students at High Tech High in San Diego, where he was also given the opportunity to participate in classes. He attended, observed and interviewed educators and artists at the Creativity Week in New York. He attended the SFPC artist presentations and interviewed teachers there, and conducted a lengthy interview with the Dean of the ITP (Interactive

Telecommunications Program) at New York University (NYU). The last leg of the Fellowship took the Fellow to Hong Kong (HK), where he organised and chaired a panel around this research. It was also another opportunity to discuss his research with many colleagues, old and new.

The Fellow found that the gap that had been identified in Australia, was also an issue in many other parts of the world. This, in the Fellow's opinion, is a consequence of a number of factors: the restrictions within educational institutes often worked against efforts to incorporate 'new' ways of working resulting in the emergence of many new educational models and community-driven initiatives operating outside of the institutions; a distinct division between the hard sciences (of which, software writing and hardware skills are seen as being part of) and the humanities and arts areas, impeding the possibility of conversations between the two; an inherent conservatism in arts education which limits what students are exposed to and a perception that software writing is for logically minded people.

The benefits to all that have been affected by the Fellow's dissemination efforts have been acknowledged multiple times. Students and parents have thanked the Fellow on many occasions for creating a makerspace and many parents have commented to that effect on the blog that documents the makerspace. Researchers have also commended the Fellow for his makerspace efforts and these comments are found on the said blog. Teachers that the Fellow has engaged with through PL workshops, meetings, consultancy and by email have all shown great appreciation for the perspective and resources that the Fellow was able to bring to the table. Undergraduate teachers have provided feedback to the effect that the Fellow's knowledge and skills dissemination has added greatly to their repertoire of tools and resources to use in their practice.

The Fellow's vocational enhancement has been extraordinary to say the least. The skills, knowledge, networks and opportunities that the Fellow has gained would not have been possible without this Fellowship.

ii. Abbreviations & Definitions

CC	Collingwood College
CNC	Computer numerical control
ESTEMEⁱ	Excellence in Science, Technology, Engineering and Mathematics Education
GUI	Graphic User Interface
DATTA	Design and Technology Teachers Association
DLTV	Digital Learning and Teaching Victoria
ITP	Interactive Telecommunications Program
ISEAⁱⁱ	International Symposium on Electronic Art
LLN	Language, Literacy and Numeracy
MIT	Massachusetts Institute of Technology
NYU	New York University
PBL	Project-Based Learning
SFPCⁱⁱⁱ	Society For Poetic Computing
STEAM	Science, Technology, Engineering, Art and Mathematics
STEM	Science, Technology, Engineering and Mathematics

Modding: an expression derived from the verb “modify”. Modding, in this context, refers to the act of modifying hardware and software, to perform a function not originally conceived or intended by the designer.

Unconference: (also called an Open Space conference) is a participant-driven meeting. The term “unconference” has been applied, to a wide range of gatherings that try to avoid one or more aspects of a conventional conference, such as fees, sponsored presentations, and top-down organization.

1. About the Fellow

1.1 Aims of the Fellowship Program

The Fellowship program allowed Greg Giannis (the 'Fellow') to investigate the delivery of software writing and hardware construction skills to creative industry students in areas including Visual Arts, Graphic Design and Digital Media, by visiting international experts and centres of excellence in order to bring back the specialist skills that had been identified as a gap in local knowledge. In order to reduce the skills gap identified through the dissemination of the research upon the Fellow's return, experts and students were observed and interviewed.

For over 15 years, the Fellow has been delivering classes to TAFE students, university students, and recently primary school students and primary and secondary school teachers, using a hands-on project-driven approach where the classroom is transformed into a makerspace,^v and invention and creativity are the focus. This approach harnesses the power of learning by doing and has proven to be a great motivator for the students and teachers taught thus far.

The Fellow expanded his knowledge and improved his methods in delivering classes and workshops by utilising best-practices; for example, block-based programming languages such as Scratch^{vi} and hardware such as the Arduino.^{vii} These two technologies alone open an otherwise inaccessible world to creative industries students and encourage creativity and engagement. The Fellow's research was used to inform and improve the methods used to teach these technologies and that of colleagues. Furthermore, the Fellow's research informed subsequent workshops for primary and secondary school children and teachers at Collingwood College, at the Reservoir Neighbourhood House and Footscray Community Arts Centre.^{viii}

1.2 About the Fellow

Dr Greg Giannis

Employment

Latrobe University

» CDL – 21st Century Digital Learners

CTA - Communicating through the Arts, 2017

» LMS - Learning Multimedia Strategies - Coordinator, 2017

» ICT – Master of Education, 2016

Centre for Creativity, Diversity and Wellbeing, Victoria University (2014 – 2015)

» Research Assistant. Development of interpretive walk Android app for Yorta Yorta Nation

Collingwood College P-12 (2015 – present)

» STE(A)M Professional Development Workshops

» Creativity Club - Makerspace

Footscray Community Arts Centre (2015)

» Scratch/Arduino Workshop (9–12yr)

Monash University (2008 – 2011)

- » Art & Design, Lecturer/Digital Co-ordinator

Victoria University (2001 – present)

- » Supervision of Masters of Education student
- » Creative Processes. Dip of CI
- » Development and Implementation of CertIV (Media Art) Training Package
- » New Media 1, 2 & 3. ADOM Dept of Creative Industries.
- » Game Programming 1, ADOM (Game Development, Art, Design & Multimedia Dept
- » Implementation of ADOM (Game Development) Training Package
- » Flash & ActionScript, Bachelor of Multimedia
- » Web Design 1, 2 & 3, ADOM, Art, Design & Multimedia Dept
- » Development of ADOM (Interactive Multimedia) Training Package
- » Major Research, EDIM, Art, Design & Multimedia Dept
- » Electronic Design 1,2 & 3, EDIM, Art, Design & Multimedia Dept

Swinburne University (1998 – 2012)

- » Web Design, Masters, School of Design
- » Web Design, New Media
- » Design for Multimedia 3, B. of Multimedia, School of Design
- » Multimedia Design Practice, B. of Design (Multimedia), School of Design
- » Advanced Web Design, IT
- » Photography, Community Theatre

- » Program Coordinator, Webskills Program
- » Computer Literacy, Multimedia Interface Design & Intro to Internet Webskills Program

Australian Centre for the Moving Image (ACMI) Master Class

- » Using Network Data for Generative Art Projects (2004)

Kodak Australia

- » Software Design Engineer – Advanced Imaging Research Dept.

NEC Australia

- » Software Design Engineer – Radio Design & Development Dept.

Memberships/Affiliations

- » agIdeas (annual international design event held in Melbourne)
- » Alumni; RMIT, Swinburne and Victoria Universities
- » Australian Centre for the Moving Image, Federation Square, Melbourne
- » Australia Council for the Arts (OZCO), Surry Hills, NSW
- » Australian Interactive Media Industry Association (AIMIA), Sydney, NSW
- » Australian Network for Art and Technology (ANAT), Adelaide, SA
- » National Association for the Visual Arts (NAVA), Woolloomooloo, NSW
- » Museum of Image and Sound, Sao Paulo, Brazil

Qualifications

Tertiary

- » PhD (Performance/Multimedia), Victoria University 2014
- » Masters of Arts (Media Arts), RMIT 1999
- » Bachelor of Electrical/Electronic Engineering, with Distinction, CIT 1985

Other

- » Certificate IV in TAE (Upgrade). 2014
- » Dip of VET, 2007
- » Certificate IV in Workplace Training II. 1998
- » OptusVision Television Production Course. March 1997
- » Desktop Video Production, Collingwood TAFE. June 1991
- » C++ programming, Dr S. Hekmatpour. October 1990
- » Occam Programming, R.Cok Digital Tech. Ctr, U.S.A. 1990
- » Computer Graphics and Visual Effects at Ausgraph. 1990
- » Freelance Journalism, Prahran TAFE. 1988
- » Certificate of Studio and Sound Recording, VAEC. 1986

Recent Exhibition Highlights

- » ISEA 2017, Manizales, Colombia 2017
- » Celebration, Big West Festival, Melbourne 2015
- » Caminando vias de agua, 12th Havana Bienale, Cuba 2015

2. Australian Situation

The Fellow's research and experience (having taught at Monash, Swinburne, RMIT and Victoria University) has revealed a gap in the incorporation of new technologies in creative industries courses. From what the Fellow has been able to ascertain through discussions with peers in the industry and the Fellow's own experience teaching in various TAFE institutes, no other TAFE courses are teaching this material to creative industry students. The Fellowship confirmed that this was a problem at an international level as well.

The creative industries include areas such as Visual Arts, Graphic Design and Digital Media. Students in these courses tend to be visual learners and communicators, and have, in the experience of the Fellow and that of the Fellow's colleagues and associates, a resistance to anything related to the hard sciences that computer software and hardware is perceived to be part of. This presents a problem and missed opportunity for artists to be engaged with a medium that is highly prevalent in our society, or as Geert Lovink^x puts it:

"We need input from critical humanities and social science that starts a dialogue with computer science on an equal basis. ... The submissive attitude towards the hard sciences and industries in arts and humanities needs to come to a close".^x

Artists need to engage with the complexity of coding in order to be better equipped to provide any critique, as this is one of the roles of an artist. Developing this criticality is a huge undertaking but a necessity and a by-product of learning to use the tools, which is a starting point.

"[W]e live, obviously, in the modern age where everything is completely controlled by machines, and we're-- in a way, -- we're kind of subservient to them, even though we might think that we aren't. So, having basic coding skills is obviously important for understanding how computers affect us socially, technologically, artistically, creatively, and so on".^{xi}

The only attempts the Fellow has encountered to incorporate any type of coding into creative industries courses has been through the use of a product known as Flash,^{xii} the main reason being that it is considered an industry standard. The Fellow's own experience has been that Flash (Adobe multimedia product) was more an obstacle to creativity than an aid as the coding side of Flash is complex and students have been observed struggling with this complexity to achieve something very simple. There are other courses that include coding but these are in specialist areas that specifically require coding and thus students are prepared and expecting to learn coding. These areas include web page authoring and game development.

Eventually a more intuitive product (Scratch^{xiii}) was trialled and productivity and engagement increased dramatically. This is but one simple example of how the gap can be reduced. Scratch is an example of a visual or GUI programming platform, developed by MIT to facilitate the teaching of digital literacy to young children, but has proven so successful that it is being used for students of all ages, including first year computer science students.

There is a great deal of evidence in the pedagogical literature for a hands-on approach to learning. The theorist Piaget championed the idea that “to invent is to learn”. Recent developments in technology have created a worldwide maker movement^{xiv} where learning is encouraged through making. The Fellow’s own exposure to pedagogical practices helped to formulate a ‘making’ approach in classrooms some 10 years ago, well before the current popularity of the term Maker. The Fellow’s pedagogy is also informed by the Reggio Emilia approach, an innovative methodology that seeks to bring out the best in every student through exploration and experimentation.

3. Skills Enhancement and Knowledge Acquisition Areas

The skill enhancement areas of applied research for this Fellowship were identified as follows:

3.1 Pedagogical approaches to incorporating new technologies into existing creative industries courses.

- » The Fellow researched examples of best practice through discussions and interviews with practitioners, leaders in the field and other researchers who have been exploring this field for some years.
- » The Fellow experimented with differing approaches in different contexts: classroom, community workshops and makerspaces.

3.2 The tools used to facilitate the incorporation of new technologies into creative industries curricula.

- » Low entry tools are necessary in order to foster engagement with conceptually complex or unfamiliar territory. The complexity can often be simply a perception fostered through students' past experiences.
- » The Fellow researched and catalogued many useful and practical tools that leaders in the field and researchers have adopted through discussions and observation.
- » The Fellow's first-hand exploration of tools.

3.3 The methods used to demystify complex technologies so that creative industries students are able to engage without intimidation, thereby encouraging independent experimentation and entrepreneurial skills.

Approaches to teaching computer programming in a creative context have been, in the Fellow's experience, a stumbling block for many students not specifically studying this field. It is becoming a need in many disciplines, and computer programming has been incorporated into the primary and secondary school curricula here in Australia (2016) and recently in the US and UK.

- » The Fellow researched methods and strategies utilised to demystify complex technologies through discussions and interviews with practitioners, leaders in the field and, in particular, students that have successfully engaged.
- » The Fellow researched in order to understand the obstacles to engagement and what aspect of the technologies students grappled with.

3.4 The utilisation of electronics and digital hardware in a creative context.

Digital technologies can be divided into two interdependent categories: software and hardware. The software (or code) provides instructions and the hardware actuates these instructions. Hardware can range from simple electronic circuits to complex microprocessors with millions of embedded components.

- » The Fellow introduced the Arduino[™] (a small hardware device that can sense and control) into classes with some interesting and successful outcomes.
- » The Fellow researched examples of best practice through discussions and interviews with practitioners, leaders in the field and other researchers to better understand the unique challenges associated with working with hardware.
- » The Fellow observed a range of students and teachers utilising digital hardware in learning, making and playful contexts to better understand the unique challenges associated with working with hardware.

4. The International Experience

The international experience is detailed chronologically in Appendix 1. What follows are extracts from the international experience situated within the Skills Enhancement and Knowledge Acquisition Areas identified previously. See Appendix 1: Chronological ordering of interviews.



Image 1: High Tech San Diego

4.1 Pedagogical approaches to incorporating new technologies into existing creative industries courses

The Fellow discussed, observed and researched the following pedagogical approaches to the incorporation of new technologies into existing creative industries courses and other educational contexts:

Project-based learning (PBL)

This approach was found by far to be most conducive to the introduction of new technologies in a classroom and in other learning environments such as computer clubs and maker spaces. This came as no surprise to the Fellow as this has been the preferred approach in his teaching practice. The research literature¹ certainly reflects the popularity and efficacy of this approach.

PBL can be implemented in many ways and one approach that the Fellow has experienced and found to be very beneficial utilises a studio-based or critical design dialogue approach. This is a mode of delivery commonly used in art and design schools, and in Reggio Emilia inspired classrooms. Students are regularly asked to show their work for feedback and peer-review in order to encourage constant iteration of works, sharing of learning and discussion. Although this has been used for many years in art and design contexts, it appears to be making inroads into other disciplines as its value is realised. Artist and teacher, Margaret Noble at High Tech High, San Diego uses this approach with great success.

1

<http://changingislearning.blogspot.com.au/2015/07/10-reason-why-pbl-10-challenges-for-pbl.html>

Interest-driven arts learning

Dr Kylie Peppler, Director of the Creativity Labs at Indiana University, uses this approach, bringing together educators, designers, artists, and learning theorists interested in constructionist and hands-on, design-based learning. The approach focuses on computational tools and materials that support learning by leveraging youths' interests in digital culture, design, and making. Much of Dr Peppler's current thinking around making and interest-driven learning is highlighted in her report, *New Opportunities for Interest-Driven Arts Learning in a Digital Age* (2013), which showcases how today's youth learn in their own time and according to their own interests through digital production tools and social media. <http://kpeppler.com/>

Related to Interest-driven arts learning is the work of the Freshed² group out of New York. The Fellow came across the Creative Tech Week Conference in New York and was exposed to many relevant topics and discussions. The group champions culturally responsive pedagogy, where the emphasis is on and recognition of students' interests and the integration of youth culture to engage and drive creative learning outcomes. Teachers at the conference were mostly artists, rappers, poets, musicians, etc. They reported many positive outcomes, including increase in academic results, retention and singing!

Play-based learning

The value of play in learning is a topical research area aiming at leveraging children's innate ability for play, and learning through play. This approach can be witnessed in makerspaces, where an informal environment with little pressure to produce an outcome encourages a playful and experimental approach to learning. This approach has been trialed in the Fellow's makerspaces, one of many dissemination activities the Fellow has undertaken since returning from overseas, and has been found to be conducive to focused engagement and to nurturing creativity. These approaches were witnessed at the various makerspaces visited and, importantly, at the Tinkerlab part of the Exploratorium in San Francisco.

Constructionism: Learning by making

This pedagogical approach as championed by the late Seymour Papert, is essentially learning by making, and has been inspiration for much of the maker movement and progressive teaching approaches and is well-aligned with PBL approaches, the two modes often working side-by-side. Papert was an expert on how technology can provide new ways to learn and was a founding faculty member of the MIT Media Lab. Papert also collaborated for many years with Jean Piaget at the University of Geneva in Switzerland. This hands-on approach to learning was witnessed in many locations during the Fellow's visits, including at the Sao Paulo Hacker Lab (mentioned below) and the previously mentioned High Tech High in San Diego.

Analogue teaching methods for computational literacy

The Fellow's visit to the Sao Paulo Hacker Lab unearthed some interesting approaches to the teaching of computational literacies through non-computational methods such as board games. The Fellow had produced similar resources many years previously when he taught computer programming concepts by engaging students in walks guided by another student's instructions, so this approach, although revelatory, reinforced the Fellow's own experimentation in this way of learning. Interestingly, this approach had been devised by the Fellow through his research in art and the practices of the Situationists. The board game in question, Code Monkey Island, was the first the Fellow had experienced. Subsequently, other similar resources were discovered, including the excellent resource CS Unplugged.³

The Fellow has utilised these resources when disseminating information and delivering Professional Learning workshops to primary school teachers who were particularly stressed about the prospect of having to teach computer coding, something they had no knowledge of whatsoever. All of the teachers were very relieved that they could utilise non-digital methods to teach the digital literacy curriculum.

The Context-driven or learner-centered pedagogical approach

Mark Guzdial, a Professor in the College of Computing at Georgia Institute of Technology, was an early advocate of computer literacy for all students, not just for students of computer science, at a time when this was a very new consideration and not on many educators' radars. He was responding to government reports about the perceived future need for computer literacy and set about implementing computer literacy instruction across a whole college. This presented many challenges as there was not a widely-held belief, as there is now, of a general need for this literacy. Nevertheless, his efforts and research are definitely bearing fruit now as the issue is of great significance. He came to the conclusion that context or, put another way, the learner's particular needs, had to be considered and incorporated into the tuition. This was contrary to the way computer science had been taught in the past, when there was a firm belief in de-contextualising the instruction intentionally so that it could be applied to many domains. Put simply, the instruction was tailored to the needs and context of the student's discipline; for example, graphic designers were taught to program in JavaScript in order to automate Photoshop processes, and photographers were introduced to digital imaging manipulation through code.

Leveraging Citizen Agency and Critical Engagement

An interesting aspect and motivation for much of the work being undertaken to engage young people with digital technologies is driven by the desire for citizen agency. Social, political, environmental, indigenous and other topical issues are inspiring citizens to engage with technologies in order to provide a means by which they can exercise agency and citizenship. The Fellow's visit to Ubalab ⁴(Ubatuba, Brazil), an experimental laboratory of open education, citizen innovation and free technologies, revealed the breadth of activities taking place in this not-for-profit grassroots organisation. Ubalab provides a meeting place for indigenous community engagement, issues and a platform for activities around the use

of public space, environmental issues (e.g. recycling and upcycling) and other community concerns as raised by the community. Similar concerns were being addressed at the Sao Paulo makerspace and at another like-minded endeavour the Fellow discovered taking place in the Amazon jungle in the northern parts of Brazil. The focus is on the issues in these places and the technology is seen as a tool facilitating citizen engagement.

The work of Natalie Jeremijenko, an internationally acclaimed artist, engineer and inventor based in New York, whom the Fellow interviewed and is now collaborating with, is relevant to this discussion of citizen agency as her work is very much about utilising creativity and technologies to address environmental issues, and, as a consequence of this, public health. Natalie Jeremijenko was named one of the most influential women in technology and one of the inaugural top young innovators by MIT Technology Review.⁵ In discussions the Fellow had with Jeremijenko, she conveyed her research outcomes and subsequent dismay upon discovering that many female engineering students dropped out because they had entered engineering with the intent of helping make the world a better place but discovered that engineering courses did not really accommodate this. This has relevance to the Fellow's research as it identifies a means by which women, under-represented in these fields, may be better engaged with STEM related fields.

Other issues related to critical engagement/citizen agency discussed with the scholars the Fellow interviewed (particularly those from UCLA) included challenging the monopolisation of digital space, tools and ways of working. This area is one the Fellow researched some years ago as part of his PhD, and is of importance as the monopolisation of digital tools, for example, can have far reaching consequences as it can dictate what is possible, and consequently normalises these restrictions, affecting what and how teachers are able to engage students.

4

<http://ubalab.org/sobre>

5

<http://gasp.org.au/2015/12/natalie-jeremijenko/>



Image 2: San Paulo Hacker Space

Critical Making

Related to the approach mentioned above, Critical Making, as a term, was initially used by Matt Ratto in 2008 and first used in a 2009 publication to describe the combination of critical thinking and hands-on making — a kind of pedagogical practice that uses material engagements with technologies to open up and extend critical social reflection.⁶

Critical Making starts with the assumption that technology is never neutral and strives to unpack the assumptions behind technological designs and increase understanding of how technological objects shape social values. The Fellow sees this as an important consideration to bring into makerspaces and into the classroom that adopts maker strategies, so that students have a broader understanding of the issues surrounding the use of technology, and an understanding of its wider social implications. These issues have come to the fore in recent times

as we realise that technologies are not passive or inert and impact our lives in ways hitherto unprecedented. The Fellow is in discussion with Garnet Hertz, a researcher in this field, and is contributing content to Hertz's books from his makerspace experiences.

A blended mode of delivery: the changing face of education

The Fellow had the opportunity to interview Dan O'Sullivan, Dean of the ITP at NYU. The Fellow had been aware of the exemplary work conducted by the students of the ITP course after meeting a student cohort in Havana Cuba in 2005, so to interview the Dean and visit the University was a dream come true. The Dean conveyed his vision for the future of the course, which has a significant bearing on changes currently being undertaken in the Australian Higher Education sector as many courses are moving to a blended mode of delivery. The ITP course is currently a two-year face-to-face Master's qualification; this will more than likely change to a blended delivery mode where a significant component of the delivery will be online and accompanied by some intensive face-to-face tuition. The school currently runs a four-week intensive unconference over summer largely driven by the participants, and this is being seen as a trial for the new blended course. An indication of the need for such a mode of delivery is the success of the SFPC (Society for Poetic Computing) course in New York, which is run over an intensive 10 weeks.

Structural changes in the delivery of education are being undertaken in many Australian universities and TAFEs. Unlike previous attempts to provide online learning that were largely driven by the institutions themselves, this time around, the changes are driven by public demand. The public is demanding greater flexibility in the delivery of education and many courses that have blended delivery modes are actually increasing their enrolments.

Related to this is the Fellow's championing of the classroom as a shared learning space, where the flow of information is not from teacher to pupil but from all in the class. The Fellow has trialed this with some very interesting results, some of which

included learning a great deal about the interests of youth and how they engage with technologies, thus informing the nature of the Fellow's subsequent classes and project work undertaken.

4.2 The tools being used to facilitate the incorporation of new technologies into creative industries curricula.

Low entry tools are necessary to foster engagement with conceptually complex or unfamiliar territory. If the tools themselves create obstacles for entry, the desired engagement may never be realised. The complexity can often be simply a perception fostered through students' past experiences.

Analogue methods for computational literacy

As mentioned above, the Fellow's visit to the Sao Paulo Hacker Lab unearthed some interesting tools for the teaching of computational literacies through non-computational methods such as board games. One particular board game Code Monkey Island, was the first the Fellow had experienced. Subsequently, other similar resources were discovered, including the excellent resource CS Unplugged.⁷

The Fellow has utilised these resources when disseminating information and delivering Professional Learning to primary school teachers who were particularly stressed about the prospect of having to teach 'coding', something they had no knowledge of whatsoever. All of the teachers were very relieved that they could utilise non-digital methods to teach the digital literacy curriculum.

Scratch

Scratch is a free visual programming tool developed at MIT. Scratch is used by students, scholars, teachers, and parents to easily create animations, games etc. It provides a stepping-stone to the more advanced forms of computer

programming and is currently taught to primary school students through to first year Computer Science undergraduates. It can also be used for a range of constructionist purposes from maths and science projects (including simulations and visualizations of experiments, recording lectures with animated presentations) in the social sciences, for the creation of animated stories, and interactive art and music. Scratch was developed by MIT Media Lab's Lifelong Kindergarten Group, led by Mitchel Resnick and Seymour Papert, Professor of Learning Research, Director of the Okawa Center, and Director of the Lifelong Kindergarten group at the MIT Media Lab.

The Fellow has used Scratch extensively, in a range of settings and has found it to be an excellent environment for engaging students of all ages in the creation of multimedia through visual programming mechanisms.

Processing

Processing is a unique programming environment originally developed for non-programmers (specifically artists and designers) by Ben Fry and Casey Rea (whom the Fellow interviewed at UCLA). Casey Reas is an artist who is known for his creative work with software. This tool allows those not traditionally targeted for programming to access this world for creative outcomes. Processing has become highly successful and utilised in many countries and educational contexts worldwide. Many programming environments or IDE's (Integrated Development Environments) are cumbersome and difficult to set up, presenting a high-floor to entry and therefore a hindrance to engagement, whereas Processing can be quickly deployed to create an app with a few mouse clicks. Furthermore, it has a very high ceiling as many contributors have written libraries greatly enhancing capabilities and possibilities.

The Fellow has made use of Processing for his own creative works and introduces it to students and teachers to whom the Fellow provides professional learning.

Minecraft

An independently produced construction game, Minecraft is a phenomenon in itself as it has had an incredibly high uptake and can also be programmed or ‘modded’. The game has received praise from critics, and won numerous awards and accolades. As of February 2017, over 121 million copies have been sold across all platforms, making it the second best-selling video game of all time.⁸

The Fellow discovered throughout the course of this research, brilliant examples of the utilisation of Minecraft in schools; for example, in the construction of models of real architecture. In one case, students measured their school buildings and grounds and reconstructed this to scale within Minecraft. Another important discovery was the ability to ‘mod’ Minecraft, effectively allowing programmatic control of the game.

Sonic-Pi and other innovative tools & new products

Sonic-Pi is a tool that allows the learning of coding through music: “Learn to code creatively by composing or performing music in an incredible range of styles from classical and jazz to EDM.”⁹ The use of this tool emerged from discussion with Kate Siccio in New York.

Many new products have emerged that target STEAM learning in schools. These are very common, and include Lego Mindstorm (a robotics platform built around proprietary hardware and software), Littlebits and an assortment of others. The Fellow has some reservations about the closed system nature of many of these products. In an attempt to simplify interaction with the products they impose limits on what can be achieved. Furthermore, these products can be expensive, lock the school into a particular way of working with a limited set of outcomes and do little to expose the inner workings of the technology that is part of the motivation for these activities. The Fellow is of the opinion that greater outcomes can be

achieved at less expense with open-source products such as the Arduino and Scratch.

The main issue is the selection of tools appropriate for the desired learning outcomes: *“In designing a construction kit, one of the most important decisions is the choice of the basic building blocks of the kit. This choice determines, to a large extent, what ideas users can explore with the kit – and what ideas remain hidden from view.”*¹⁰



Image 3: The Exploratorium San Francisco

8 <https://en.wikipedia.org/wiki/Minecraft>

9 <http://sonic-pi.net/>

10 <http://web.media.mit.edu/~mres/papers/IDC-2005.pdf>

4.3 The methods being used to demystify complex technologies for creative industries students.

There is considerable overlap between the pedagogies, tools and the methods used to demystify complex technologies, some of which have already been discussed in the previous sections: namely, the approach used by Guzdial in contextualising programming instruction to raise the relevance of programming for students not specifically studying Computer Sciences, and the use of non-digital games for teaching of coding principles introduced to the Fellow at the Sao Paulo Hacker Lab. In this section, the methods utilised not covered previously will be discussed.

At the Creativity Lab at Indiana University, the Fellow was exposed to practices that utilised craft-based analogous activities to enhance learning in seemingly unrelated complex areas; for example, the researcher, **Sophia Bender**, was exploring the use of knitting and weaving to enhance understanding of mathematical concepts. She explained that there is considerable complexity and mathematics in both knitting and weaving, and by encouraging and utilising these activities it is possible to engage a previously disengaged cohort in disciplines such as mathematics. An interesting aside is the connection weaving has to coding's historical roots: the first computer programs were used to automate a weaving machine.

Traditional activities such as sewing and patternmaking were also being explored at the Creativity Lab for their potential to inform the teaching and learning of two-dimensional and three-dimensional mathematical concepts amongst other things. This has led to the development of shelters (tents, geodesic domes) for homeless and emergency situations, clothes for dolls (e.g. Barbie dolls) and puppets, cosplay costumes (tapping into a costume-based youth culture that engages both genders) and, as an extension of this, e-textiles, where electronics and clothing combine.

Following is a summary of the discussions the Fellow had with people working in this area of demystifying complex technologies.

Naomi Thompson & Anna Keune, from the Creativity Lab discussed their bio-simulation project with the Fellow. BioSim [is] a participatory simulation where young students (grades K-3) enact the roles of honeybee and army ants in biological systems through the assistance of computer-enhanced e-puppets [and] is designed to elevate youths' understanding of complex systems through novel combinations of play, reflection, interaction, and exploration.¹¹ This provides a very novel and engaging means by which young students are able to engage and understand systems thinking.

Mr Tarrey from The Project School (Bloomington, Indiana) and **Mishael Sedas** from the Creativity Lab discussed the class project that involved students from many levels (mixed level classes) collaborating to construct an aquaponics system.¹² It is a highly engaging, integrated project that covers many curriculum areas with a real-world application.

Margaret Noble from High Tech High in San Diego alerted the Fellow to the wonderful video resources of Daniel Shiffman's (ITP, NYU) coding videos.¹³ The style and tone of these video tutorials alone appear to make a significant difference to the reception of this knowledge. Margaret Noble has successfully used these videos to assist students in understanding the complexity of text-based coding. The Fellow was able to witness this in action during the visit to High Tech High and also discuss Daniel Shiffman's videos.

Daniel Shiffman also works with exploring natural phenomena through coding with his Nature of Code series of instructional videos. This is a nascent area of coding for many and draws on replicating natural phenomena in order to engage and inspire students to work with coding. Related to this is a large field of practice known as software art, where software is used in art contexts.¹⁴ Casey Reas,

11 <http://www.creativitylabs.com/popbio.html>

12 <http://www.mishaelsedas.com/blog/arduino-microcontrollers-and-aquaponics-systems-in-an-awesome-middle-school-classroom>

13 <http://natureofcode.com/>

14 <http://www.codingforart.com>

whom the Fellow interviewed, is a proponent of this art form. He co-authored processing;¹⁵ a coding environment for artists and designers.



Image 4: DrawBots

4.4 The utilisation of electronics and digital hardware in a creative context

Digital technologies can be divided into two interdependent categories: software and hardware. The software (or code) provides instructions and the hardware actuates these instructions. Hardware can range from simple electronic circuits to complex microprocessors with millions of embedded components.

Hardware itself has been addressed in some cases in the previous sections; namely, **Sophia Bender** from Creativity Lab explored cosplay and e-fashion in order to engage students, and **Mr Tarrey** from The Project School & **Mishael**

Sedas from the Creativity Lab engaged with hardware through the building of an aquaponics system. The following discussion relates to hardware issues that have not been mentioned previously.

The **Arduino**¹⁶ and all its variants (e.g. Lilypad), has become one of the main hardware platforms for makers and educators around the world. It is an open-source system that has captured the imagination of many and has a strong community. The other main competitor is the **RaspberryPi** even though they address significantly different requirements. The Arduino is utilised to support, amongst other things, e-textile work. **Sophia Bender** identified a problem that the Fellow had also experienced when using Arduino hardware in workshops, the conclusion being that this type of hardware is better suited to older students, as it requires fine motor skills and basic electronics knowledge.

The Exploratorium's (a public learning laboratory in San Francisco exploring the world through science, art, and human perception) approach utilised physically large objects for electronics and this was much more successful as it addressed the problem of fine motor skills, the disadvantage being that this approach is more restrictive in what is possible. The Fellow is of the opinion that there is a need for a bridge between this approach (i.e. that of the Exploratorium in its use of large tactile electric circuit components and the more intricate Arduino).

Other methods witnessed included scaffolding the introduction of hardware through 'fun' activities such as DrawBots (vibrating very-simple robots for drawing random patterns) for simple understanding of electronics and paper circuits. The Fellow trialled paper circuits at a few workshops and public events and found that they engaged the public in an activity that produced electronic pop-up gift cards.

Toy Hacking is an activity that the Fellow has successfully run at Collingwood College makerspace for many months and it continues to fascinate many young students. It provides a simple means by which young people are able to investigate

15 <http://processing.org>

16 <https://www.arduino.cc/>

electronics and in doing so learn significantly about the use of tools, multimeters and how simple circuits work. As mentioned previously, this activity has been documented at the blog dedicated to this makerspace: <http://blog.facade.net.au>. The Fellow has also unearthed some research literature around toy hacking and pedagogy from **Karen Wohlwend**, another member of the Creativity Lab.

Many are extolling the virtues of devices such as 3D printers for makerspaces and engagement. It is of the Fellow's opinion that these devices need to be carefully considered before being adopted as they do not lend themselves to the engagement that many assume. The Fine Art department at the University of Indiana, where the Creativity Lab is situated, makes interesting use of 3D printers for exploring jewellery, metal-smithing and sculpture. Likewise, a polystyrene foam and CNC cutter is also being used in architecture, ceramics and etching. These are productive and engaging uses of this technology and so well suited to creative disciplines.

5. Recommendations

Image 5: Creativity Lab Maker Space

Recommendation 1: Makerspaces

General discussion and rationale

Makerspaces (aka fablabs, hacker spaces and tinker spaces) have been shown to be effective in encouraging engagement in STEM related areas by providing an unstructured and informal environment without the constraints of time and assessment to explore and experiment.

The maker movement is now a global movement as it exhibits and incorporates proven pedagogical advantages such as constructivism, it engages all ages, and is generally an informal unstructured learning environment that encourages creativity, experimentation, tinkering and play. The Fellow's international exposure to makerspaces and local experience in running three makerspaces and providing consultancy since his return has highlighted the enthusiasm that the public have for makerspaces, and communities are growing all around the world. Some are mobile events that are incursions into smaller communities such as the Labmovel (from Gisela Domshke, Sao Paulo) and Pedro (maker lab in Sao Paulo and mobile lab) or Kate Sampson's Central American Journey,^{xvi} whereas others are commercial enterprises and/or not-for-profit organisations that provide a range of services to the public, including access to maker facilities. Examples of newly formed commercial enterprises are Inspire9^{xvii} at the DreamFactory^{xviii} in Footscray and Western BACE^{xix} in Melton. There are a few not-for-profit spaces such as Connected Community Hackerspace,^{xx} Make-Create^{xxi} in Brunswick and Footscray Makers Lab. Many of the commercial enterprises have received start-up funding^{xxii}

from the state government, clearly indicating the perceived importance of these endeavours.

Makerspaces have other advantages in that they:

- » Engage and facilitate the teaching of STEM skills, which has become an Australian and international priority for governments;
- » Support the Digital Technologies ¹ curriculum delivered for the first time in 2017;
- » Inspire self-directed learning;
- » Facilitate interdisciplinary collaboration;
- » Develop innovative ideas by making use of new technologies, and build knowledge sharing networks and communities;
- » Engage kinaesthetic learners who are often overlooked in traditional educational organisations;
- » Gain an understanding of experimental and iterative design approaches;
- » Quickly become familiar with emerging technologies; and
- » Build supportive and encouraging community and lasting friendships.

The Fellow's vision for makerspaces is as a facility that:

- » Accommodates children of all ages, from primary through to secondary;
- » Encourages teachers pre- and in-service to observe, engage and trial ideas;

¹ <http://victoriancurriculum.vcaa.vic.edu.au/technologies/digital-technologies/introduction/rationale-and-aims>

- » Provides a place to run PL for teachers;
- » Offers specialised classes whose teachers may use the space and its resources in the same way students move to another facility for other classes (e.g. art);
- » Accommodates parents and extended families who may also wish to make use of the space to support their kids or to learn themselves;
- » Encourages artists (local, invited, self-initiated, residency, exhibition etc) who can often bring fresh ideas and stimulate others;
- » Supports makers, designers, hobbyists;
- » Offers short courses; and
- » Encourages fabrication, experimentation and critical making.

Although largely a recent initiative and championed by a few progressive academics and practitioners, “[c]ritical making is an intensely trans-disciplinary process, one that requires research skills from humanities and social science disciplines and a familiarity with a wide range of scholarly literatures. At the same time, critical making requires some technical expertise on the part of the researcher, who must curate a technical experience for participants with little or no technical background”.^{xxiii}

The role of government in makerspaces

The role of government is to provide incentives for the establishment of makerspaces at schools and in the community. Governments are supporting makerspace start-ups, as discussed above, and providing some competitive funding for schools to facilitate the implementation of the digital literacy curriculum through makerspaces for instance. Arts are being subordinated to STEM priorities despite research advocating the importance of arts education for future employability skills, and for improved engagement when integrated with STEM activities. This is a concern and needs to be addressed as soon as possible as there is important learning that occurs through the arts, learning that involves skills that are recognised as being important for future generations: creativity, communication, collaboration and critical thinking.

There are international examples of governments initiating these spaces as an indication of their perceived importance; for example, whilst in São Paulo, the Fellow discovered, “In February 2015, city authorities in São Paulo announced plans to open a network of 12 public FabLabs. Following in the wake of an earlier ‘telecentro’ initiative that opened up internet access and digital media to citizens, the FabLabs are meant to bring the tools of digital fabrication to the people, equipping them for a fuller role in what FabLab founder Neil Gershenfeld foresees as a revolution in the decentralisation and democratisation of production and consumption.”^{xxiv}

“The emerging maker movement is the new mineral to mine and the future of industry in Australia.” (Deloitte 2014:6)

The role of industry in makerspaces

Industry can play a major role in supporting makerspaces through sponsorship, donations and discounts. Industry can also help by alerting governments and educational institutes to future needs rather than immediate shortages. Furthermore, industry can facilitate the creation of makerspaces by providing informal learning opportunities, internships, mentoring and work placements. And, as mentioned previously, makerspaces themselves are being embraced by industry and entrepreneurs and are being created as entities within themselves. There are also many managements looking at makerspaces within their organisations to foster creativity, communication, collaboration and critical thinking.

“Over the last decade, the maker culture has grown tremendously and now schools and companies see the need to have physical spaces to encourage making, hacking, learning, and collaborating. Terms such as fab labs, innovation spaces, hacker spaces, DIY, and makerspaces can be interchangeable.”^{xxv}

The Fellow initiated a collaboration with VU Hanger (a start-up stimulator) and ran a makerspace to support the work of VU Hanger in 2016. The continuation of this in 2017 is still under negotiation.

In order to support the makerspace initiated at Collingwood College K-12 (discussed below under Education), the Fellow initiated a discussion with Dion Stojsavljevic (general manager, market development and innovation) of Solvup, “a cloud based technology, developed to improve customer experience in retail while minimising the economic and environmental impact of unnecessary returns.”^{xxvi} Essentially, this company provides a service to retailers, handling all of the returns, many of which are discarded or simply given away. The general manager was more than happy to redirect some of these returns to the makerspace at Collingwood College for the benefit of this community.

The role of education in makerspaces

The Fellow created a makerspace in 2016, the Collingwood College Creativity Club, with an emphasis on creativity that is documented at <http://blog.facade.net.au>. The makerspace at CC is a trial of the efficacy of an informal learning space to support students, pre- and in-service teachers and families. This is being supported by the principals through the allocation of space and some limited funding. This is continuing in 2017. The Fellow has applied for a Commonwealth Digital Literacy School Grants (DLSG) grant and is awaiting a decision.

The CC makerspace drew the attention of many students and parents, all of which is documented in the above-mentioned blog. The Fellow utilised donations from the community to provide a space for tinkering, play and creativity. The outcomes were highly original and engaging for those who attended, garnering the praise of a leading researcher in the field, Kylie Pepler (Director of The Creativity Labs at Indiana University), whom the Fellow visited and has maintained contact with.

“Wow, I love this blog! Super pictures and excellent writing that so captures the creativity at play! Truly, it’s some of the most creative work that I have seen to date— so much of it is becoming a collection of iconic projects (which are great) but really nice to see some projects breaking the mold. I can only imagine how much work this is on your end!! Incredible!”^{xxvii}

The Fellow also initiated a Makerspace at the Victoria University library as a test of the efficacy of an informal learning space to support students and in-service teachers. This was a totally different experience and one that was facilitated by correspondence with the manager of the Curtin Makerspace at Curtin University. Despite the general acceptance of the benefits of a makerspace, dedicated support for this endeavour is limited. This will continue in 2017 but there are some logistics that need to be sorted before commencing.

The makerspace at VU was utilised by existing TAFE colleagues to show students the possibilities and opportunities provided by the space to support their learning. These spaces could also be observed by pre-service teachers in education, as is the case with students from Education at Latrobe University where observation of makerspaces is compulsory and integrated into their curriculum. All the Master’s students whom the Fellow has supervised reported the benefits of observing students at work in a makerspace. They are seen as an adjunct to learning and facilitate the acquisition of extra skills, as has been the Fellow’s experience. TAFE Creative Industries teachers acknowledged the importance of these spaces as a means of diversifying their delivery by integrating with ICT. For example, many artists are working with digital technologies but this is seldom taught at any art school in Australia, and overseas for that matter. A makerspace would give the opportunity to those creatives who want to explore ICT options. Aligning this with the entrepreneurial initiative (Hanger) at VU TAFE provides pathways for budding inventors.

The Fellow is negotiating with the Faculty of Education at Victoria University to provide maker incursions into their ICT classes. This is a positive and welcome addition to the students’ studies by all the academics involved.

The role of community in makerspaces

Community makerspaces are emerging in various forms, some as informal gatherings but mostly as commercial enterprises. Schools are leveraging the expertise of their community to create ‘clubs’ around coding and hardware (e.g.

robotics). There are many meet-ups facilitating coding (for example) and other smaller enterprises (e.g. Laneway learning) that create learning opportunities through collaboration and use of hired spaces. The Fellow has conducted workshops at community centres, all of which have been very popular. He has been invited to conduct more and is currently negotiating doing so in 2017.

Recommendation 2: Professional Learning for existing primary, secondary, TAFE and HE teachers

General discussion and rationale

In order to best support TAFE teachers in the future, the Fellow proposes a shift in how the Vocational Education and Training (VET) sector views and values research. As a VET employee, the Fellow's own research activity is not formally recognised, despite the manifold benefits that can and have emerged from this fellowship. The Fellow's capacity as an educator has expanded considerably, engaging teachers from all educational sectors, students and families in projects that engage and educate in new and contemporary ways, providing pathways to digital literacy outcomes. ISS Institute has a significant role to play as an advocate in this process. ISS Institute is one of few avenues for TAFE to grow its knowledge on an international scale.

Given the importance and urgency in the implementation and delivery of the digital technologies curriculum at primary and secondary school levels, it is necessary to make a concerted effort to train and up-skill the teachers already in the workforce. Discussions with teachers in various PL sessions and other events have highlighted the anxiety and fear ("to be honest, I'm scared!") felt by many that do not have a good grasp of ICT and yet are expected to deliver. The curriculum requires implementation from primary years through to the end of high school, across a range of subjects where possible, but with dedicated subjects in the two final years of high school. Without adequate support, much of this will be delegated to subject areas that seem to fit (e.g. science, maths), foregoing the opportunity

to truly integrate STEM studies across disciplines, an integration that has been shown to foster better engagement.

In discussions with the DLTV, the Fellow was informed that the government granted a half-day in 2016 for PL. Given the urgency, it is surprising that there is not more support. The Fellow's research has uncovered similar problems existing in other countries that are implementing a digital technology curriculum. In the UK, teachers' forums are replete with complaints from teachers struggling to adopt the new curriculum with very limited governmental support. Communities are responding to this by leveraging volunteers from industry, and teachers are left to pursue their own professional development mostly in their own time.

An article published in *The Age* highlights the urgency of the support required for teachers.^{xxviii} The article claims that only one in three teachers is prepared to deliver the digital literacies curriculum. The Fellow's opinion is that this may be an optimistic figure, judging from his own experience in working with in-service teachers.

The role of government in PL

The government needs to provide greater support for educators in order to best adopt this curriculum. Otherwise, and as is the case now, many teachers will incorporate it in less than ideal ways; for example, relegating it to a few subject areas seen to be better suited to delivering (e.g. maths), and eliminating the possibility of integration across subject areas where the curriculum is ideally situated. Some scholars^{xxix} are also seeing computational literacy as a new literacy that may be best supported as part of current LLN initiatives. This would certainly be a welcome move as computational literacy is an expectation in many workplaces.

In summary, the Fellow is of the informed opinion that there needs to be greater support for teachers to effectively engage with computational and digital literacies, and that the government needs to play a greater role in enabling this. This could

be achieved through, for example, funded sabbaticals, and other research opportunities. Given the importance of this curriculum it may be prudent to engage specialist teachers or experts, assigned to each school to assist with training and implementation, and the running of a makerspace.

Participation of industry in PL

In the same way that many voluntary and not-for-profit organisations have emerged to support teachers, industry could play an important role in providing PL that is better aligned with industry requirements.

The role of the education sector in PL

This is crucial for teachers who are delivering in 2017, and is more so with high school teachers as primary school requirements are simpler to accommodate and can be addressed with strategies that do not require computers. This also raises some issues with alternate pedagogies; for example, Steiner and their policy of no computer use at primary school. The Fellow assisted Steiner teachers at CC by supplying resources (e.g. Computer Science Unplugged) that allow for the teaching of curriculum requirements without the use of a computer. This was also a very popular recommendation for teachers at Thornbury Primary School for whom the Fellow has provided advice and PL.

TAFE teachers tend to be focussed on specific skill delivery as dictated by training packages. There is no imperative for them to adopt an integrated curriculum although, in the Fellow's experience, this has proven to be better for engagement. There is a strong case for the delivery of computational literacy across the whole spectrum of disciplines as it is being compared to other forms of literacy, such is its relevance in contemporary life. But this may take a shift in thinking that many are not quite ready for. In terms of delivery of ICT skills to creative industries students, the Fellow has had some success in the makerspace started in the TAFE library. Teachers from the creative industries have attended and discussed the possibilities of the technologies and have sought advice. This makerspace is developing in response to the interests of students and teachers and will evolve

to provide a more accessible facility. It is strongly supported in principle by the Fellow's manager and the library staff.

The Fellow has been able to modify existing courses that he delivers given the knowledge gained from the Fellowship and this has thus far been an improvement in terms of engagement and participation. Furthermore, the Fellow has been able to influence the development of a subject in the new Advanced Diploma of Visual Art at Victoria Polytechnic. This subject, New Media Arts, delivers the training package unit CUAACD602 - Extend professional expertise across new art forms and media.

TAFE teachers have limited time allocation for Professional Development (the current Enterprise Bargain Agreement stipulates 42 hours per year) and limited opportunities for research as part of their work.

The role of the community in supporting PL

The wider community can play a significant role in supporting PL for teachers. Parents can influence their children and prepare them for the curriculum by steering their computer usage towards activities that can help them to learn but are also recognised as being 'fun' by a wide international cross-section of young people; for example, Minecraft modding and Redstone, which involve problem solving and computational thinking, and Scratch, a multi-media authoring environment built around a block-based coding platform. Parents and guardians may even consider learning alongside them as the skills (computational thinking, creativity, critical thinking and communication) are recognised as being applicable to all ages. These students can become valuable assets to the classroom, assisting both students and teachers as the Fellow has experienced first-hand.

Many community centres are recognising the popularity of many of the creative digital tools discussed and are offering workshops to young people. The Fellow has run many of these workshops and they have always sold out quickly as they appeal to both genders equally (the 9–13 age range) and are very much in demand.

Mentoring is something to be highly encouraged. This can happen in many different ways, and can be an unintentional outcome of a friendship or a by-product of a professional relationship. The Fellow has informally mentored a high school science teacher who had experimented with integrated anatomy lessons, utilising simple electronics, lighting and garment construction. Over a period of months, the Fellow had irregular, informal meetings with the teacher during which resources and knowledge were exchanged. The teacher undertook a 6-week intensive at NYU ITP Summer Camp, in New York. This teacher will be an invaluable resource to the education community.

Recommendation 3: Training of pre-service teachers

General discussion and rationale

Pre-service teachers have the opportunity to position themselves strategically in relation to the Digital Technologies curriculum. Much of this will depend upon their own specialisations and their exposure to this curriculum. The Fellow's experience thus far has been surprising in discovering that exposure to the new Digital Technologies curriculum has been very minimal to undergraduates in the Education faculty he teaches into. Masters students who specialise in ICT are cognisant of the curriculum but not the undergraduates. The Fellow is providing opportunities for the students to learn and be exposed to the curriculum in the subjects he is teaching.

Teachers will also have to consider changes to their pedagogy. We are living in a time where many students are engaging with ICTs in ways that adults are simply not aware of. Teachers may never be able to keep ahead of the students, resulting in great anxiety for many teachers used to delivering to students. The Fellow addresses this issue by engaging the students in the projects and allowing them to bring their unique knowledge and expertise into the classroom for the benefit of all, including the teachers. The Fellow has learnt a great deal from this shift in pedagogy and has found students to be generally more receptive and engaged if their knowledge is celebrated, shared and valued. This was an important

lesson learnt from the research around youth's interest-driven media art practices undertaken at the Creativity Lab at Indiana University.

The Fellow has and continues to champion PBL as an effective and engaging pedagogical strategy. The Fellow observed this approach in the Reggio Emilia inspired classes at Collingwood College in which he participated over a period of three years as a volunteer. The Fellowship has only consolidated the Fellow's belief in the efficacy of this mode of working, witnessing excellent examples at, for example, High Tech High in San Diego.

The Fellow is also arguing for more cross-disciplinary integration (e.g. maths and dance) as this has proven to foster greater engagement, learning and variety.

The role of government in the training of pre-service teachers

- » Scholarships for teachers specialising in ICT to encourage greater uptake.
- » More funding and time to support student teachers.

The role of industry in the training of pre-service teachers

Could practicums involve a short residency in a relevant industry? Currently pre-service teachers will undertake a work placement as part of their training. The Masters students the Fellow has supervised have been directed to the makerspaces established in several high schools in order to observe and learn. This has been made part of their assessment and all pre-service teachers report that the experience was very rewarding and informed their practice. Makerspaces are appearing in many guises. Some are established as fabrication co-workspaces and allow participation and use of the facilities on a subscription basis.

The role of education in the training of pre-service teachers

The Fellow is supervising a Masters of Education student at Victoria University; he taught an ICT unit in the Masters of Education programme at Latrobe University in

2016 and Learning Multimedia Strategies and Communicating Through the Arts at Latrobe University in semester 1, 2017.

Recommendation 4: Collaborations

General discussion and rationale

Collaborations with international leaders, exemplars and others in the field with common interests creates many affordances. Amongst these are:

- » Opportunities for the sharing and access to knowledge and skills that may otherwise have gone unnoticed
- » An increased awareness of the activities of scholars working in parallel fields but who, by virtue of distance, language or other impediment, remain unaware of each other's work
- » Access to foreign facilities and equipment that may not be available in the home country
- » Access to unique sites and populations, giving other insights into the research at hand
- » Personal inspiration, ambition and reputation
- » Encouraging further or additional links and enhancing future funding opportunities.

Government

The Fellow believes that the government should provide initiatives that support national and international collaborations enabling educators and policy makers to keep abreast of advances in pedagogy and strategies, across disciplines. ANAT as an example of a government-funded organisation that encourages and helps establish art and science collaborations. Encourage, provide frameworks and funding of practices that support the sharing of knowledge and examples of

best-practice. The Fellow's overseas experience highlighted an ethos of sharing of knowledge through documentation of processes for the benefit of all; as a reflective and recording tool for the practitioners themselves, a means to encourage discussion and debate and to share and disseminate knowledge. This contrasts with a reluctance for Australian educators to share and document their practices and findings. The Fellow acknowledges that part of the problem is time. This seemed to be the one constant complaint amongst all teachers. One exception that the Fellow is aware of, are the schools that have adopted the Reggio Emilia influenced pedagogy. This pedagogy stresses the importance of documentation of students' work and having experienced this first-hand through volunteering and observation can immediately see the benefits of such a practice.

Industry

In order to address funding and resource restrictions, educational organisations in the UK have created an after-school coding program run mostly by volunteer developers from industry.

The Fellow is currently collaborating with a leading artist/innovator, co-authoring engaging STEM related resources based on this artist's projects. (<http://nataliejeremijenko.com/>)

Education

Encourage local, district, state, national and international collaborations. The educators that the Fellow engaged with through the Fellowship were all characterised by a culture of documentation and sharing of practices and outcomes for the greater good. Blogging is a common method as it has manifold advantages: it allows for the educator to document and reflect on their processes and methods, allows others to learn from these experiences and enter a dialogue and provides access to resources to an international audience.

The Fellow is maintaining contact and regular conversations with educators he met during his Fellowship. This will pave the way for future collaborations, exchanges and ongoing debate.

Discussions with Community Development TAFE staff for possible collaboration leveraging makerspace as a community building space.

Treat class projects as collaboration to encourage exchange of information amongst teacher and students.

Community

Invaluable for fostering relations amongst students, parents, teachers and the broader community of volunteers, mentors, etc. provides informal learning situations as has been experienced in the CC makerspace.

Recommendation 5: Conference and other Presentations

Opportunities for sharing findings and disseminating information should be encouraged at all levels. It allows practitioners to engage in a larger dialogue with peers and industry experts that can provide commentary and feedback, and further opportunities for collaboration.

Government

International government approaches and comparisons and examples of best practice.

Industry

Conferences include industry representatives, and therefore an opportunity to engage with their needs and requirements. For example, during an industry launch the Fellow had discussions with a representative from the TIC group in Tottenham

and discovered a very unique resource. Further discussions led to the Fellow being given access to salvaged electronics for use in makerspaces.

Education

The Australian education sector is currently grappling with the implementation of the digital literacies curriculum. The Fellow has had many opportunities to present to schools on this topic, including Collingwood College, Mt Alexander College, Thornbury Primary School, Methodist Ladies College, Templestowe College, Gilmore College for Girls and has presented to the ESTEME group of schools that meet on a regular basis to share and discuss pedagogical approaches including STEM integration and EAL. Furthermore, the Fellow has presented to TAFE and HE colleagues and in various PL sessions.

The Fellow organised, solicited engagement from other interested parties and presented a panel discussion at ISEA 2016 in HK, with Murray McVeitch, Vikki Moulder & Hugh Davies. This was an excellent opportunity for information exchange and networking, greatly enriching the research and sharing this with others.

Pop-up open day for Victoria Polytechnic where many discussions were had with TAFE teachers.

Community

A pop-up makerspace at the CC Spring Fair provided many opportunities for discussions with parents regarding the digital literacies curriculum and the makerspace's role in supporting this. The pop-up makerspace was overwhelmed from start to finish, making it a very productive day as the message was received by many parents.

Recommendation 6: TAFE Employment and Course Restructuring

Government

Government policies can cripple sectors of the education system, as has been the case with the reduction in TAFE funding as implemented by the last Victorian Liberal government. Many places simply shut down, whilst others remained but with lesser offerings. This has put many educational institutes in survival mode, where little time can be spent on restructuring and implementing new priorities and pedagogies, to the detriment of all stakeholders. My place of employment has had very little time and/or resources for restructuring courses. Employees have been pushed to their limits and any additional activities simply cannot be afforded. The top restructuring priority has been the conversion of many courses to a blended-learning mode of delivery. This is being implemented incrementally as it is a huge undertaking. Therefore, any resources available have been directed to this priority.

The TAFE system is governed by Training Packages that dictate to a large extent the content delivered. The Training Packages seem to apply well to some areas of training whilst they are not suitable in other areas where a competency-based assessment is mostly inappropriate and does not capture the richness of the students' work and their learning. I am speaking of my own experience and the application of the Training Packages to the creative industries as defined above. The pedagogies identified by the Fellow that are appropriate to addressing the knowledge gaps identified do not fit well within a competency-based assessment system. Student-initiated, project-based learning requires flexibility and will often provide a richer learning environment and experience for the students.

Providing specific training for a workplace that is constantly changing is meaningless and may leave students with irrelevant and therefore, useless skills and knowledge. The skills that are being asked for by employers are generic and not specific. We need to teach students to think for themselves and to be able

to learn for themselves. The resources are available for any student with the time and discipline to acquire a plethora of skills and educational institutes may render themselves redundant if they don't pay attention to the changes that are taking place.

Industry

There has been a great deal of discussion around the needs of industry in relation to what students need to learn in order to be relevant in the coming years.

Education

The Fellow's own course area has been affected by structural changes to pedagogical approach as a result of Fellowship. This has affected three subject areas or 7 units.

The Fellow will develop a unit in the Advanced Diploma of Visual Arts to provide opportunities for students to think creatively with ICT through coding and hardware.

Structural changes in international course offerings occurring in response to student demand and dissatisfaction with existing institutional offerings. For example, Dean of NYU ITP programme indicated that two year masters course would be reduced to a leaner blended mode of delivery. Mostly online and some intensive face-to-face.

Community

Rise of alternative, community-based training organisations in response to dissatisfaction with existing institutional offerings.

Online access greatly increases learning possibilities for many.

6. Knowledge Transfer: Applying the Outcomes

This section is a more general statement, whereas the recommendations section provides detailed actions and outcomes from initial implementations of these recommendations.

1. Makerspaces

» What?

Makerspace at CC as a test for the efficacy of an informal learning space to support students, pre- and in-service teachers and families.

Makerspace at VU library as a test for the efficacy of an informal learning space to support students and in-service teachers.

Makerspace at The Hanger at VU's MetroWest alongside Hanger entrepreneurial initiative.

Providing consultancy services to schools implementing makerspaces

» Why?

Makerspaces have been shown to be effective in encouraging engagement in STEM related areas by providing an unstructured and informal environment without the constraints of time and assessment to explore and experiment.

» Who?

The Fellow has initiated the makerspaces in consultation with principals, education managers and other interested parties such as parents and students.

» How?

The Fellow approached the principal at CC to discuss the establishment of a makerspace. Was provided with a space and some basic resources, starting informally and allowing to grow organically through consultation with all stakeholders including students, teachers, parents and wider community.

» When?

Makerspaces were initiated in 2016 and will continue in 2017. Principal at Collingwood College has provided a new dedicated space, more equipment and we are awaiting the outcome of a government grant. Senior Manager at Victoria Polytechnic has approved Fellow's continuation of maker activity in lieu of other obligations. The Fellow has been approached by other representatives from other primary and secondary schools. Negotiations will continue in 2017.

2. Professional Learning

» What?

Facilitated Google CSHS grant that provided funds for PL sessions at VU.

Provided advice, sourced funding and consultancy to organisations providing PL for primary and secondary school teachers; for example, STEM Centre at VU, RNH & Collingwood College.

Provided PL directly to teachers in the primary, secondary and tertiary sectors.

» Why?

PL is in urgent need as many primary and secondary teachers feel that they are not equipped to deliver the curriculum.

» Who?

Thus far the Fellow has conducted PL on his own and with colleagues. In a few instances, PL was provided by teachers that the Fellow has mentored.

» How?

The Fellow initiated the above-mentioned PL opportunities through discussions with colleagues, primary and secondary school teachers that he has developed a relationship with through other voluntary activities and parents.

» When?

The abovementioned Professional Learning activities took place in 2016 and will continue in 2017. The Fellow is awaiting the outcome of a Digital Literacy School Grants that will determine to what extent he will be able to continue the Professional Learning activities.

3. Training of pre-service teachers

» What?

Supervise Masters of Education students (Latrobe and VU)

Teaching in the Education department at Latrobe University

» Why?

Supervision of Master's students and teaching undergraduates allows for targeted dissemination of knowledge and skills to a cohort that is looking specifically at ICT delivery in the education sector.

» Who?

During 2016 The Fellow supervised a Victoria University Masters of Education student who was a regular assistant at the makerspace the Fellow runs at Collingwood College. This supervision will continue in 2017. The fellow facilitated an online ICT subject for Masters of Education students at Latrobe University. Other work for 2017 has yet to be finalised.

» How?

Employment in HE is precarious, often short-term and unpredictable as it depends on enrolment numbers that fluctuate from year to year. The Fellow has made contacts in the sector through interviews and his research. These colleagues contact the Fellow when work is available and in response to the Fellow's enquiries.

» When?

Initiated and conducted in 2016 and 2017. Subsequent opportunities will be dependent upon fluctuating enrolment numbers.

4. Collaborations

» What?

Collaborate with teacher in San Diego exploring mutually beneficial opportunities

Continue dialogue and explore collaboration possibilities with Assoc. Prof. Kylie Pepler, Creativity Lab, Indiana University

Collaborate with Assoc. Prof. Natalie Jeremijenko to develop STEM curriculum with an emphasis on creative agency and environmental health

Collaborate with colleagues introduced to at Creativity Lab, UI. (e.g. Kate Samson who is undertaking makerspace facilitation in Central America)

Collaborate with globalreconciliation.org in order to explore the opportunities that a makerspace can contribute to social concerns and global reconciliation

» Why?

Collaborations with international exemplars has the potential to enrich the skill set of Fellow and others that can participate in the collaboration, and provide ongoing professional development for the fellow, and ongoing dissemination beyond the fellowship.

» Who?

The Fellow has maintained contact with the abovementioned exemplars through email, and other forms of online communication. These have proved to be highly valuable as they allow the fellow to discuss issues with exemplars in the field.

» How?

Online communications systems and persistence as many of the exemplars are very busy people.

» When?

These collaborations were initiated during the Fellowship and continue to this day.

5. Conference and other Presentations

» What?

Presentation to colleagues in TAFE sector

Presentations to ESTEME network of teachers

Convened a panel and presented at ISEA 2016 conference

Paper submissions to international conferences. Awaiting outcomes.

» Why?

Panel presentation at international conference focused on creativity and technology revealed many gaps in delivery of ICT at an international level. Dissemination of information and research findings to colleagues and other teachers.

» Who?

The Fellow has undertaken delivery of presentations and the convening of the panel at the ISEA conference.

» How?

Conference panel initiated by calling for interested parties in co-authoring a paper and presenting at conference. Panel then needed to be peer-reviewed before acceptance. Presentations to colleagues and ESTEME group initiated by the Fellow.

» When?

Completed late 2016. Anticipating further opportunities in 2017 as awaiting paper results of conference paper submissions.

6. TAFE Employment and Course Restructuring

» What?

Recognition and encouragement of TAFE research

Restructuring of courses as detailed below

» Why?

Opportunity for other VET sector teachers to benefit as has the Fellow

Improve students' outcomes by incorporating pedagogical changes to course areas

» Who?

The Fellow and colleagues at Fellow's places of employment

» How?

Government educational and employment policies will need to change to accommodate research within the TAFE sector. Currently there is no provision or time allocation. Restructuring of courses implemented by the Fellow in consultation with colleagues and education manager.

» When?

Changes to government policies are beyond the control of the Fellow. Course restructuring has commenced in 2016 and will continue in 2017.

There has been a great deal of information and skill dissemination by the Fellow upon his return from overseas. The Fellow realised a sense of urgency amongst primary and secondary school teachers as the new Digital Literacies curriculum had to be delivered in 2017, and many teachers were ill-prepared to deliver. As a consequence, Professional Learning was delivered to many in-service and pre-service primary and secondary school teachers. Leveraging the relationship with Collingwood College, the Fellow initiated and has been running a makerspace at the college since mid 2016. The makerspace was visited by international researchers and the Fellow was interviewed, giving this small humble space international exposure.

The work at the makerspace was also highly commended by Dr Kylie Peppler, head of the Creativity Lab at Indiana University, one of the sites the Fellow visited. Furthermore, dissemination of skills and knowledge has taken place because of the Fellow's employment at La Trobe University since 2016, where

he is teaching undergraduate and post-graduate students in the Education faculty. Other avenues of skills dissemination undertaken thus far, include: a makerspace at the Victoria University library; a makerspace at a community center, Metro West, in Footscray and influence over course content in the TAFE programs the Fellow engages with.

Added to the above-mentioned activities, the Fellow is pursuing the following avenues for knowledge and skills dissemination at the time of writing.

Thornbury High has shown an interest in establishing a makerspace and the Fellow is awaiting further correspondence. A Connected Learning initiative at Victoria University, The Hive, has requested the Fellow conduct workshops for HE teachers, the first of which was attended by the Labor Government deputy leader The Honourable Tanya Pliibersek, and VU's Connected Learning Director, Trish McCluskey is currently negotiating employing the Fellow. Increased responsibilities at La Trobe University will allow the Fellow to have greater influence over course content. The Fellow has been accepted to present a workshop at the uLearn conference in NZ. Short courses for Victoria Polytechnic are being currently planned around the skills and knowledge the Fellow acquired as a result of this Fellowship, and recently the Fellow has commenced investigating the possibility of a collaboration with scientists from the DSTG (Defence Science and Technology Group).

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9. Acknowledgements

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- » Department of Education and Training (DET)
- » VET Development Centre
- » Higher Education and Skills Group
- » National Centre for Vocational Education (NCVER)
- » Creative Victoria
- » Australia Council for the Arts

Industry:

- » Educators from primary, secondary and tertiary institutions
- » Artists
- » IT Industry
- » Creativity is a skill that is required by many industries.

Professional Associations:

- » DLTV
- » DATTA

Education and Training:

- » TAFE Sector
- » Higher Education Sector
- » Higher Education and Skills
- » Victoria Polytechnic – TAFE division of Victoria University

- » Collingwood College P-12
- » Sunshine Secondary College
- » Centre for STEM Education, Victoria University
- » School of Education, College of Arts, Latrobe University
- » ESTEME Educators Network
- » Teachers from schools that participated at the VU STEM workshops.

Community:

- » GlobalReconciliation.org
- » Footscray Community Arts Centre
- » Reservoir Neighbourhood House
- » Artists working with software and hardware
- » Families of children attending primary and secondary schools

10. Appendix 1 - Chronological ordering of visits

A) Brazil - Sao Paulo

Marcelo Godoy

Associate and friend of the Fellow that is involved in the creative industry and was able to organise meetings with relevant people in Sao Paulo and other parts of Brazil.

Pedro Markun – Sao Paulo Hacker Lab

Pedro's motivation is to engage young people around issues of citizenship and social justice through the hacker lab.

- » One manifestation of this involved the “hackerbus”. A crowd-sourced enterprise that utilised a portable maker space that toured Brazil for a year. There was much enthusiasm from many of the communities visited, and he did not simply deck out a bus with computers despite this being the expectation of many participants. He encouraged a broader idea of technology e.g. cardboard as a building and prototyping material.
- » The Fellow discovered many resources through discussions with Pedro, e.g. robot board game to teach children programming – this knowledge and resource has already proved invaluable for learning computational thinking in an educational setting that does not make use of computers at primary school, as is the case with Steiner education.
- » A permanent makerspace was far more effective than a temporary intervention

- » Lock picking as a means of accessing forbidden space. Pedro relayed the story of how the first hackers were able to access computers i.e. “we wouldn't be here if these guys couldn't pick locks.”
- » Utilising big data to create stop motion animation.

Paula Carolei - Sao Paulo Hacker Lab

Paula is involved with many projects to do with education. She has developed a course that introduces teachers to a range of pedagogical approaches.

Gisela Domshke & Marcus Bastos - Educators

Gisela met with the Fellow as had been planned although her time was very limited. She provided the Fellow with a book documenting the labmovel initiative (mobile maker space) which provided a great insight into one of the major projects she had undertaken in recent years. She invited Marcus to the meeting whom it was a great pleasure and inspiration to meet.

Marcus had had similar experiences to the Fellow teaching software to students from the visual arts but more success with design students. Unfortunately there was little time to discuss why this was so and what strategies he used to overcome this problem, but was in agreement with the Fellow's experience and found art students the most difficult to engage, and encourage to explore a medium outside of their comfort zone.

Gisela teaches mostly post-graduate students and therefore is working with a body of students that tend to be more focused. Fewer problems with engagement but her teaching approach is quite experimental and risk taking. She commented that her students generally were very engaged and respected her risk taking as it provided a richer experience for the students. She outlined a few simple strategies she uses to commence her classes:

- » Finding out about the interests of her students through playful interventions, e.g. bring three items from home that are in some way important to you. This also assists to break the ice, help students know each other and can create the foundation for subsequent work. This and other processes used came from many sources.
- » Creating situation where students can get to know each other
- » Utilising the above-mentioned information to start developing their subsequent projects
- » Many of Gisela's courses are offered for free so she usually has full control over content and assessment requirements. Does not need to address others assessment criteria.
- » "Did any students leave the course because it was not the educational experience they expected?" Many left their jobs!
- » We discussed the problem of incorporating innovative methodologies and content into a course where there are expected outcomes and assessment requirements. There was agreement on the challenge that this presented, and that the educator needed to take risks and experiment with differing approaches.
- » According to Gisela, the free software movement which was encouraged and advocated in Brazil by progressive and innovative educators is responsible for a generation of software literate practitioners and educators today.

B) Brazil - Ubatuba

Felipe Fonseca – Ubalab

<http://wiki.ubatuba.cc/doku.php>

<http://ubalab.org/>

The Fellow presented the work Peripato Telematikos to a group of teachers and other interested parties as requested. The Fellow later discovered that 3 of the audience where geographers so confirmed his knowledge and understanding of critical cartographic practices. "Ubalab is a core of experimental digital culture joint in Ubatuba, north coast of São Paulo. It was developed within the network MetaReciclagem by Felipe Fonseca . In 2010, he was selected in the digital culture of public notice of the Ministry of Culture."

There are three of Ubalab actuation axes:

- » collaborative mapping;
- » experimental digital culture and MetaReciclagem;
- » knowledge exchange.

Felipe also organized Tropixel Labs, the fourth edition of the event that works on the border between art, science, technology and society in Ubatuba / SP. It happens between 22 and 24 October, following the National Week of Science and Technology.

- » Felipe discussed two current strands of work:
- » working with local indigenous communities producing subjective mappings with care taken to ensure that these mappings could not be used against them as has been his prior experience (and that of others in the Fellow's experience (ie Wilcock), and

- » the reuse of discarded electronics. recycling electronics workshops with MFA students from Qatar
- » reclaiming public space, e.g. currently building a children's playground
- » much of what the Fellow encountered has to do with critical engagement about the technologies themselves but more so utilising the technologies in the service of addressing or bringing attention to critical issue such as the environment (Jeremijenko), activism, public space, indigenous land rights, etc.

C) Brazil – Santarem, in the state of Pará

Adriane Gama - email exchange:

"I'm Adriane Gama, I am a biologist, free software activist and the coordinator of the Collective Puraqué, 16 years ago, in Santarem, in the state of Pará, developing social and digital activities, metarecycling, environment, digital culture and now, maker culture .

I coordinated a digital space, a program of the Federal Government with the support of the City hall and State, called Casa Brazil Santarem, located in around 10 districts with audio workshops, video, film club, theatre, library, programming and computer Basic and desktop publishing for children, youth and adults. Unfortunately for change of different parties' governments, this project ended.

I was acting in the Health and Happiness Project as art educator and educadora the Extractive Reserve Tapajos Arapiuns, working directly with children and young people. I recently spent the Master of Education from the Federal University of Pará and I chose to find the maker movement with the theme: Spaces maker culture experiments: analysis of new children's learning contexts from the intervention of collaborative practices in a riverside community Extractive Reserve Tapajos-Arapiuns.

And now, I'm looking for partnerships and experiences of shares on this topic and it was when I saw a post from Pedro Markun saying that you were going to talk about this subject. I was interested in his work and hope you can inspire me in my research.

My big challenge is to define what kind of maker culture activity I will develop with local children in their telecentres and school laboratories directly in the forest, combining local knowledge with scientific, mediated by environmental awareness and critical appropriation of technology."

D) UCLA (University of California Los Angeles)

Casey Reas - co-creator of processing <http://processing.org>

Casey is a leading software artist, co-creator of the Processing development environment and educator. The Fellow was looking forward to this meeting with great anticipation. Many of the colleagues that had agreed to meeting declined at the last minute which was most disappointing.

Casey strived to teach a way of thinking in the domain of the visual arts, utilising the coding system that he co-designed, processing. For example, he starts with simple co-ordinate system and how to draw using software. Student work is assessed according to its visual impact and not just the code itself. Processing was devised as a way around the steep learning curve associated with other programming languages. It is free, plus platform and has low entry. I discussed the software studies initiative with Casey and he wished that he could dedicate more time to this in his classes as he feels that is it is a very important issue. Casey alerted me to the following resources:

- » Understanding Computer Programming as a Literacy.pdf – Fascinating article discussing the criteria by which a system is considered a literacy and how computational literacy fits.

- » <https://www.kadenze.com/> Kadenze brings together educators, artists, and engineers from leading universities across the globe to provide world-class education in the fields of art and creative technology.
- » The Minecraft Generation - interesting comments and history on the use of 'blocks' in pedagogy. http://www.nytimes.com/2016/04/17/magazine/the-minecraft-generation.html?_r=0

Kate Hollenbach - teaching assistant

It was a great pleasure and highly informative to interview Kate. She came from a varied background including the computer science industry and media arts. Her initial exposure to coding was in 2nd grade i.e. logo used to draw things.

- » Teaching assistant - programming (processing), network media
- » Most students from design and media arts, all undergrads do interactivity subject. Usually a diverse group that may have some prior knowledge/interest, others not at all and many resistant to having to learn coding. Subject incorporates some CS students wanting to learn design, but only accepted if there is sufficient room. Some students in UI/UX, and outcomes of course spread by word of mouth. e.g. subject outcome is a portfolio website for graduation and for many this was the main incentive, therefore differing motivations for studying subject. Younger students have less internalised resistance to coding, as opposed to those (older) that believe that they are not good at coding, but it is not clear what this position is based on. Gender also plays a role in that more women are likely to identify with not being able to code, as does a perception that for certain practices coding does not apply or is not considered relevant; "I am an artist".
- » On software studies: John Maeda - Design by Numbers, ownership and agency of software tools. Kate considered that the tools can restrict what can be achieved. (The Fellow had crossed this research area in his Phd and recalled the arguments put forward by Walking and Manovich). As an exercise to demonstrate this, students were set an assignment to create a poster, but

without using the Adobe suite. It proved to be a powerful exercise, where students realised how beholden they are to these tools. Teacher also reported on experience as a software developer, realising that certain user-interface improvements would not get implemented due to restricted development time. e.g. PS toolbar, AND new ways of working. e.g. MS ribbon, revoked due to public outcry despite its benefits.

- » Kate also questions the neutrality of software and hardware, for example facial recognition software, Microsoft's AI bot, and algorithms, and is of the opinion that computer science education needs to teach social responsibility. There is also the question of data bias, for example Google's language translator and the racial bias of search engines. This field has become highly controversial.
- » In relation to hardware, Kate has experienced a snobbish attitude to the use of things such as the arduino in the engineering faculties. As a result, these are discouraged from use as they perceived to be not technical enough, despite their incredible popularity. This is a problem as it restricts collaboration with the engineering department because of difficulties in communication. Therefore, it is important for students to develop a vocabulary to be able to communicate with other faculties.

Hsinyu Lin - student

Hsinyu came from a performance/fine art background that added an interesting and not too common perspective. This student worked in Hollywood after her undergrad but was very unhappy despite the financial independence it gave her. Some of her work involves the construction of Chinese worker identity, for example workers in the controversial Foxconn factory. She has also produced video works about the pirating of trademarks in China. She found coding challenging and in relation to the creative process added another layer of complexity. Knowing what you want to achieve and then working towards that seemed at odds with the process used in her fine art work, such as performance, for example.

E) Luigi Anzivino - Exploratorium, Tinker Lab (San Francisco, USA)

The Fellow visited the Tinker Lab at the SF Exploratorium, the museum of science, art and human perception, a place famous for its activities. The Tinkering Studio Content Developer, Luigi Anzivino provided a guided tour and discussed many of the Exploratorium's initiatives primarily in education and community engagement. The Fellow had the opportunity to purchase some excellent books relating to the Tinker Lab itself, the founder's philosophy and pedagogy.

There are many activities taking place here, students from the county apply to work here, are paid and mentored, learn to run workshops, talk to people, and can make use of the workshops for their own projects. There is a concerted attempt to provide this to broad range of students including those that may not otherwise have much interest in science, etc. Furthermore, artist residencies are situated here in order to provide a range of stimulating approaches to the facilities and resources.

Upon his return to Australia, the Fellow completed an online Tinkering course provided by the Exploratorium which was very interesting and informative.

F) Margaret Noble – High Tech High Charter School (San Diego, USA)

One of the highlights of the Fellow's trip was to visit Hi Tech High (San Diego) and the teacher, Margaret Noble. Margaret had responded to a query the Fellow had posted on the Processing forum. Margaret is one of the few educators the Fellow interviewed to seamlessly incorporate coding practices into her art studio class. The Fellow spent several days talking to Margaret and her students, and was delighted to see the level of engagement and confidence. Hi Tech High, is a charter school where all lessons are conducted using a PBL approach. Charter schools are independent schools in the US funded by the government. Margaret

touched on coding in her fine art undergrad but was very discouraged by the complexity and poor teaching methodology. She revisited coding years later as she felt that it was something that she wanted to incorporate into her art practice, and subsequently discovered the Processing platform. This Processing platform, as discussed earlier, was developed specifically to enable artists and designers to write code for creative outcomes. It has the advantage of low-entry as it is possible to setup the system and run an example program in a few mouse clicks. As a result, it has had a huge uptake and is well supported through online resources and forums (<http://www.processing.org>). A great resource are the videos of NYU ITP lecturer, Daniel Shiffman (<http://codingrainbow.com/>), who is also author of "The Nature of Code" which can be read for free here <http://natureofcode.com/>.

Margaret's process for her project-based classes resembled a studio-based or critical design dialogue (Kehoe) process. Processes that she would be familiar with from her fine arts undergrad. There has been a renewed interest in this educational approach in fields such as Computer Science as it is seen to encourage important educational faculties:

"For over a century, studio-based instruction has served as an effective pedagogical model in architecture and fine arts education. In this model, students iteratively develop solutions to a series of design problems. Each iteration culminates in a "design crit" (design critique) in which students present their evolving solutions to their peers and instructors for feedback and discussion." from The "Prototype Walkthrough": A Studio-Based Learning Activity for the Next Generation of HCI Education, p2

"Critical design dialog engages students in the acts of communication, critical thinking, and collaboration." ibid p3

<http://www.codingforart.com/> This website covers entry level explorations in creativity through the practice of computer programming by Daniel Shiffman

G) Indiana University – Creativity Lab (Bloomington, Indiana, USA)

Creativity lab was the highlight of the Fellows' visit. The Fellow interviewed fascinating and inspiring people working with creative applications of technology in education. The creativity lab is run by Kylie Pepler. The Fellow was given an office to work from and conducted interviews with most of the team at Creativity Lab.

Justin – MILL Manager

<http://education.indiana.edu/collaboration-outreach/outreach/mill/index.html>

The Fellow's first interview was with Justin who runs a makerspace (MILL make innovate learn lab) in the department utilised by pre-service teachers. The Fellow observed an exhibition of a small selection of works created by pre-service teachers using art to teach non-art subjects. The art education teacher, Moshmi, argued that art created an emotional engagement with the work. The space was initiated by Kylie Pepler. She recognised a need after installing such a space in a community school. It is an "ok to fail" space and not all high technology. The Fellow observed the physicality of the makerspace, and its relationship to the Reggio Emilia idea of space as the 3rd teacher: large transparent plastic bins, mobile cabinets, lots of shelving and tools such as laser cutter, 3D printer, conductive material, copper tape and many materials. The Fellow was also alerted to the work of Karen Wohlwend who is writing about toy hacking, an activity the Fellow has experimented with in the CC Creativity Club with great outcomes. This has led to further investigations on repair culture, which is of interest to the Fellow as an important strategy for environmental sustainability and strategies for the integration of such issues into education.

Sophia Bender - e textiles & re-crafting maths

E-textiles

Sophia Bender's aim was to create maths lessons for lower grades utilising textiles. She used Lily Pad (an arduino variation specifically for combining electronics and textiles) and simple circuits with something called Schemer that is now out of production. The Fellow tried to find further information on this system and found some successors. It is an interesting system that uses light to program!! Sophia reported that the kids biggest barrier for sewing was fine motor skills. The Fellow has had similar experiences when conducting workshops for kids. Sophia trialled workshops in libraries, museums, girls in stem days, etc. Other issues that Sophia found influenced the success or otherwise of this type of integration: teacher training, hardware stability (modkit & ardublock communications) issues. The conclusion was that many of these activities are better suited to older kids.

Re-crafting maths

Sophia was exploring how to draw out mathematical content within textile crafting. "Recrafting maths explores the implicit and explicit mathematics and STEM related concepts tangled into traditional female fibre arts practices. We are exploring this through embedded ethnography, e.g., joining a crafting group and learning along with its members, and interviews of experienced crafters". <http://re-craft-edu.blogspot.com.au/> Sophia was also exploring connections between weaving and computer programming as they share some characteristics and have historical connections.

Other areas of Sophia's research:

- » Sewing and 2d to 3d spatial reasoning; considered mathematically 'edgy', for example when designing a sewing pattern, the pattern maker essentially needs to create a 2d pattern that will fit a 3d object. Traditionally this is an

embodied process as the pattern can be crafted directly onto the 3d body. The investigation started with observation of crafters and sewers. The Fellow, intrigued by this process and reflecting upon his own experiences created a corset for his daughter in order to better understand the complexities involved.

- » These investigations led Sophia to observe practising sewers and crafters of mixed ethnicities to understand the manual practices from an ethnographic perspective. She started noticing how good crafting practices can produce better outcomes in other areas of related research.
- » Mending and up-cycling.
- » Scale model of shelter/tent using fabric (The Fellow alerted Sophia to the work of artist Lucy Orta)
- » Workshops to make 'barbie' clothes
- » Cosplay, a costume-based youth culture that engages both genders
- » Costumes for puppets, combining e-textiles/re-crafting maths concepts
- » <https://plus.google.com/+SophiaBender> and <http://creativitylabs.blogspot.com/>

Naomi Thompson & Anna Keune

Complex systems for grades 1/2 and systems thinking utilising e-textiles and bio-simulation

- » Anna was particularly concerned with portfolio practices of makerspaces, referenced in "open portfolios" book.
- » She pointed to the site <http://youth.digitalharbor.org> as an exemplar of these practices
- » The Fellow was able to discuss the relevance of Reggio Emilia inspired documentation practices and emphasis, and Anna related that her research endeavoured to know how portfolios can be used for assessment

- » The fellow was shown the current biosim project, which involved children playing with bee puppets in order to understand systems thinking. The children were required to run around a room taking bees from flower to flower searching for the ones with the most nectar. The bees had a life (through embedded electronics) so that if they didn't find nectar in time would die. They learned that by dancing, the bees communicated location, so devised dances to help all bees survive.
- » The bee puppets were considerably large (football size), and the flowers were colorful and huge too.
- » A wonderful project that allowed the kids to learn about systems (among other things) in a very fun and engaging way.

Kate Sampson

A geologist, with a philosophy degree, interested in music and embodied cognition, a knitter curious about how things work, and prone to pulling things apart, Kate was fascinating to talk to and was keen to be interviewed despite not being on campus. The interview was conducted via skype.

- » Kate participated in a central American fab labs tour, (all documented at her blog, <http://katesamson.xyz/make2016/>) and was eager for assistance. The Fellow was invited to participate but this was not possible, unfortunately. Kate also discussed the floating fab lab traversing the Amazon river, bringing maker activities to remote communities along the Amazon (<http://amazon.fablat.org>)
- » The fellow has maintained regular contact with Kate through Google Hangouts. These conversations have been a great opportunity to share and discuss ideas around makerspaces with a scholar working at the Creativity Lab at UI
- » Kate recently alerted the Fellow to a new initiative created by Dr Kylie Pepler which is a fascinating experiment in alternate modes of pedagogy that addresses many of the issues that are seen to be problematic with education (<https://www.lrng.org/>)

Mr Tarrey

A middle school teacher from a local charter school, working with the CL to provide practical case studies and resources for teachers, reported on the progress and activities of his class and students. He initiated and utilised a makerspace in the school and is interested in re-crafting mathematics, through activities such as shelter design.

The classes at the school were structured as “institutes”, 35 students from K-8 (i.e. a very mixed level cohort which had its own challenges), have 4 maths institutes to choose from and it was considered success as all students walked away with some type of shelter.

- » This approach was tweaked after the first iteration, more materials were added e.g. canvas, fibreglass rods, etc. This encouraged 5-6 students to sew in the second session, in contrast to the first iteration where fabrics were simply draped over sticks. Tent/yurt-like structures as shapes began to emerge.
- » Lessons learnt from the first and second iterations resulted in the idea of institutes be scrapped, fewer students with less of an age span and the specification of initial parameters: textile-based, shelter of some kind, free standing, and the imposition of more constraints and boundaries to increase creativity. Some examples of outcomes: 8th grade pre-algebra class had picked shelter design, e.g. pop-up shelter for disaster relief and geodesic domes (B. Fuller).
- » Other examples of projects conducted in class included: a rooftop garden, solar-powered chicken coop and an aquaponics system.
- » Students may be asked to make their own lesson plans, and were always being asked to reflect. Formative and summative reflection opportunities abounded. All students had to present their work and were often engaged in learning that may not be apparent to learners/teachers. Video analysis was used to document processes, record student progress and as research data. Despite the obsession with digital methods, physical mockups were still considered very important.

- » Biomimicry was being considered for the following year, comprising of 4 - 6 modules including themes such as shelter, transportation and wearables.
- » “Institute of Biomimicry - The Common World Childhoods Research Collective is an interdisciplinary network of researchers concerned with children's relations with the more-than-human world. Members work across the fields of childhood studies, early childhood education, children's geographies, environmental education, and Indigenous and environmental humanities.” (<http://commonworlds.net>)

Mishael Sedas

- » A PhD student, with a mechanical engineering undergrad, Mishael is interested in engineering learning for primary schools. He originally wanted to work in the developing world (his background) and subsequently worked in Africa with the UNESCO Save the Children program, and IT teaching. Currently working with the school teacher Mr Tarrey, mentioned previously in this report, on the aforementioned aquaponics project. Inspired by Blikstein, he believed in the democratisation of technology, education and makerspaces, and sought ways to get younger students excited about engineering. He learned the programming language C in his engineering undergrad and hated it, describing it as painful, a not too unusual response in the Fellow's experience.
- » Co-creator of ‘handimate’ glove to control real world objects through gesture (arduino controlled), originally open source but commercialised as advised by Kylie.

“The combination of technological progress and a growing interest in design has promoted the prevalence of DIY (Do It Yourself) and craft activities. We introduce HandiMate, a platform that makes it easier for people without technical expertise to fabricate and animate electro-mechanical systems from everyday objects. Our goal is to encourage creativity, expressiveness and playfulness. The user can assemble his or her hand-crafted creations with HandiMate--s joint modules and animate them via gestures. The joint modules are packaged with an actuator, a

wireless communication device and a micro-controller. This modularization makes quick electro-mechanical prototyping just a matter of pressing together velcro. Animating these constructions is made intuitive and simple by a glove-based gestural controller. Our study conducted with children and adults demonstrates a high level of usability (system usability score 79.9). It also indicates that creative ideas emerge and are realized in a constructive and iterative manner in less than 90 minutes. This paper describes the design goals, framework, interaction methods, sample creations and evaluations methods.”

Larice Thoroughgood

Larice discussed and demonstrated the large physical bee models created with embedded electronics. The project and all the code and resources required to duplicate is detailed here: <http://www.iu.edu/~biosim/beesim/>

BioSim—a participatory simulation where young students (grades K-3) enact the roles of honeybee and army ants in biological systems through the assistance of computer-enhanced e-puppets—is designed to elevate youths’ understanding of complex systems through novel combinations of play, reflection, interaction, and exploration.

Ryan - Fine Art Department, UI

Manager of the Fine Art dept. fabrication space that utilises 3d printing, laser cutter/etcher and CNC router. The 3D printer is an SLA printer (FormLabs Form II SLA 3D printers which create objects with greater detail using a very different process. The SLA stands for Stereolithography. and utilises laser and resin). The software utilised is Rhino 3D. This course was originally taught by Nicole Jacquard. Nicole is an Associate Professor of Jewellery, Metalsmithing and Sculpture at Indiana University in Bloomington, IN. <http://www.nicolejacquard.com/nicole/Bio.html>

Nicole utilised the 3D printers for exploring jewellery, metalsmithing and sculpture. So essentially the fabrication space allows for the exploration of computer modelling for fine art.

There was no teaching of hardware or software writing skills in this course, only the teaching of skills needed to create 3D content and to drive a 3D printer. The Creativity Lab and the Fine Art department seemed quite removed from one another. This was surprising considering the research being undertaken in the Creativity Lab, which was asking the question: why are Fine Art departments not teaching hardware and coding skills given that many artists are utilising these mediums in their work? This was at the core of the Fellow’s investigation and the knowledge gap the Fellow identified here in Australia, was one that persisted in many other parts of the world.

Projects explored by the fine art students inc: sculpture students - polystyrene foam and CNC cutter, architecture, ceramics, etching using the laser etcher (have pics of much of this). The space engaged students from fields outside of fine arts too. opendesk.cc - furniture fabrication design that can be cut using CNC router.

H) Creative Tech Week Conference & Exhibitions (New York, USA)

The Fellow stumbled upon Creative Tech Week upon arrival in NY and spent several days listening to presentations and attending related exhibitions and concerts. Much was gleaned from this event that was relevant to the Fellow’s research. Summary of highlights:

Fresh Ed

Culturally responsive pedagogy (<http://freshed.urbanarts.org>). Great emphasis on and recognition of students' interests, integration of youth culture to engage and drive creative learning outcomes. Teachers mostly artists, rappers, poets, musicians, etc. subsequent increase in academic results, retention and singing!

The Fellow concurs with the methods presented by Fresh Ed as it has been an important means by which to better engage students and is of possibly greater relevance when attempting to engage students with the often-unfamiliar subjects of software writing and hardware development. A stumbling block has been a lack of knowledge of youth popular culture on the part of the Fellow, but allowing students to lead as has been shown by Fresh Ed and in the Fellow's recent classes creates an environment where information is exchanged rather than delivered and the teacher has an opportunity to be informed, whilst empowering students and validating their interests in the process.

Kate Sicchio

Kate Sicchio is a friend of the Fellow so it was a happy coincidence to meet at this conference. Kate, who teaches at NYU IDM and Parson's, spoke about her work with live coding, wearables and dance. The Fellow interviewed Kate on a separate occasion to discuss her work in more depth, and attended a presentation she gave at SFPC. Kate's work is an exemplar of the possibilities afforded when an artist works with technologies. Coming from a dance background, but eager to explore further possibilities, Kate and her cohort, Camille Baker have produced a ground-breaking body of work. Kate incorporates these practices and the teaching of technical skills to her students, so her feedback regarding how she goes about this was invaluable.

- » NYU IDM, Masters - wearable technology (elective)
- » creative coding compulsory

- » students from diverse fields: media studies, journalism, fine art, paralegal, activism, gaming
- » based in Brooklyn so attracts many women of colour
- » collaborations with Pratt Inst of Design, which is strictly an art/design school
- » Parson's MFA Design & Tech, diverse cohort of participating students
- » practice based thesis

Kate provided a PDF of students' final work, and alerted the Fellow to the product SonicPi (Post-Doc output from Sam Aaron), a tool that facilitates the learning of coding through music. "Learn to code creatively by composing or performing music in an incredible range of styles from classical & jazz to EDM." <http://sonic-pi.net/>

Seth Indigo Carnes

Created "Poetics" an art iphone app [<http://www.poetics.me/> & <http://www.sic.ph/poetics/>], like magnetic words on fridge that can be re-arranged that is being utilised by teachers.

- » an example of arts-centred learning, Columbia/NYU
- » multimodal literacy: touch, gesture, symbol, text, image, speech, movement, language and culture
- » Seth drew parallels with artists working in this way e.g. Dada, cut-up, Burroughs, chance
- » What interests the Fellow with this work is the intersection of art and technology and its use in teaching and learning.

Mozilla Learning Networks [teach.mozilla.org]

Great online resources and community. Curriculum - free, open & educator-tested.

- » • amira@mozillafoundation.org
- » • emphasis on Web-Literacy

Dan O'Sullivan - Dean of NYU, ITP

The Interactive Telecommunications Programme at NYU-Tisch is a 2 year Masters programme the Fellow has been aware of since meeting a group of students in Cuba in 2003. This course is an exemplar in this field teaching hardware and software writing skills to a range of students including artists and designers. The Fellow interviewed the Dean, Dan O'Sullivan, and discussed the structure of the course and its future. The school has been running an intensive summer camp in un-conference mode over the last few years. This is 4 weeks long and is an intensive immersion in all things that the course teaches driven by participant presentations and workshops. The Dean informed the Fellow that this 4-week intensive is actually a trial for the future direction of the course; short intensive face-to face sessions with significant online tuition. This is what is commonly referred to as blended learning, a significant shift in pedagogy being adopted by many educational institutes in response to demand from students seeking greater flexibility with their learning.

SFPC (Society for Poetic Computation)

The Fellow attended a series of presentations and had discussions with teachers and students from this small non-accredited school. Their course is run over an intensive 10 weeks, reflecting a student-driven demand for shorter courses. The course is well attended with more applicants than available places. The Fellow came to the conclusion that this course and in particular, its intensive structure was to be expected and a sign of the future of education particularly in light of the conversation the Fellow had with the Dean of the ITP course. Many other similar shorter courses are also referenced on the school's website indicating a growing trend in this mode of delivery.

Susan Hinton

The Fellow visited an ex-student whilst in New York that was working as a developer for Kickstarter, and is now employed by Microsoft. This student was inspired by the creative technology possibilities introduced to her in a class presented by the Fellow. She moved to the US, began blogging her creative technology interests and quickly developed a name for herself in the industry, went on to give several TED talks and presents at conferences internationally. Her experience in the US was not always smooth, having been exposed to sexism in a predominantly male industry, but through perseverance and dedication she was able to carve out a significant presence in the industry.

I) ISEA Conference Panel Presentation with Murray McVeitch, Vikki Moulder & Hugh Davies

One of the Fellow's recommendation is to seize opportunities to attend and present at conferences and other situations where information can be exchanged and networks can be created or extended.

The Fellow was able to organise, solicit engagement from other interested parties and present a panel discussion at ISEA 2016 in HK.

One outcome from this conference attendance was that the Fellow was able to meet Natalie Jeremijenko, a world-leading artist and innovator with a great interest in STEAM, for the purpose of fostering creative agency and addressing environmental health issues through art.

Natalie Jeremijenko

The Fellow is currently collaborating with Natalie Jeremijenko in the authoring of a book. The book will provide secondary teachers and students with innovative and engaging projects based on her own creative works, for the delivery of STEM education. The Fellow was offered the opportunity to co-author after interviewing Natalie, and this process is currently underway.

11. Endnotes

- i. SFPC is an artist run school in New York that was founded in 2013. A small group of students and faculty work closely to explore the intersections of code, design, hardware and theory — focusing especially on artistic intervention. It's a hybrid of a school, residency and research group. <http://sfpc.io/>
- ii. <http://inllen.org.au/initiative/esteme-excellence-science-technology-engineering-mathematics-education/> international
- iii. ISEA International (formerly Inter-Society for the Electronic Arts) is a non-profit organisation fostering interdisciplinary academic discourse and exchange among culturally diverse organisations and individuals working with art, science and technology. The main activity of ISEA International is the annual International Symposium on Electronic Art (ISEA).
- iv. <https://en.wikipedia.org/wiki/Unconference>
- v. "A makerspace is a collaborative work space inside a school, library or separate public/private facility for making, learning, exploring and sharing that uses high tech to no tech tools." from <https://www.makerspaces.com/what-is-a-makerspace/> last accessed 25/2/2017
- vi. <http://scratch.mit.edu>
- vii. <http://arduino.cc>
- viii. <http://footscrayarts.com/event/extreme-arts-app-creation-and-hardware-hacking/>
- ix. Geert Lovink, founding director of the Institute of Network Cultures, is a Dutch-Australian media theorist and critic. <http://networkcultures.org/geert/>
- x. Art in the Global Present Papastergiadis & Lynn (Ed.) <http://epress.lib.uts.edu.au/books/art-global-present> p107
- xi. Dr Jon McCormack an artist and academic based in Melbourne, Australia interested in the creative possibilities of computers and computation, in particular how computers can enhance our creativity. <http://jonmccormack.info/~jonmc/sa/about/>
- xii. <http://www.adobe.com/au/products/flash.html>
- xiii. <http://scratch.mit.edu>
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- xxix. Understanding Computer Programming as a Literacy, Annette Vee. <http://licsjournal.org/OJS/index.php/LiCS/article/view/24> last accessed 25/02/2017



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