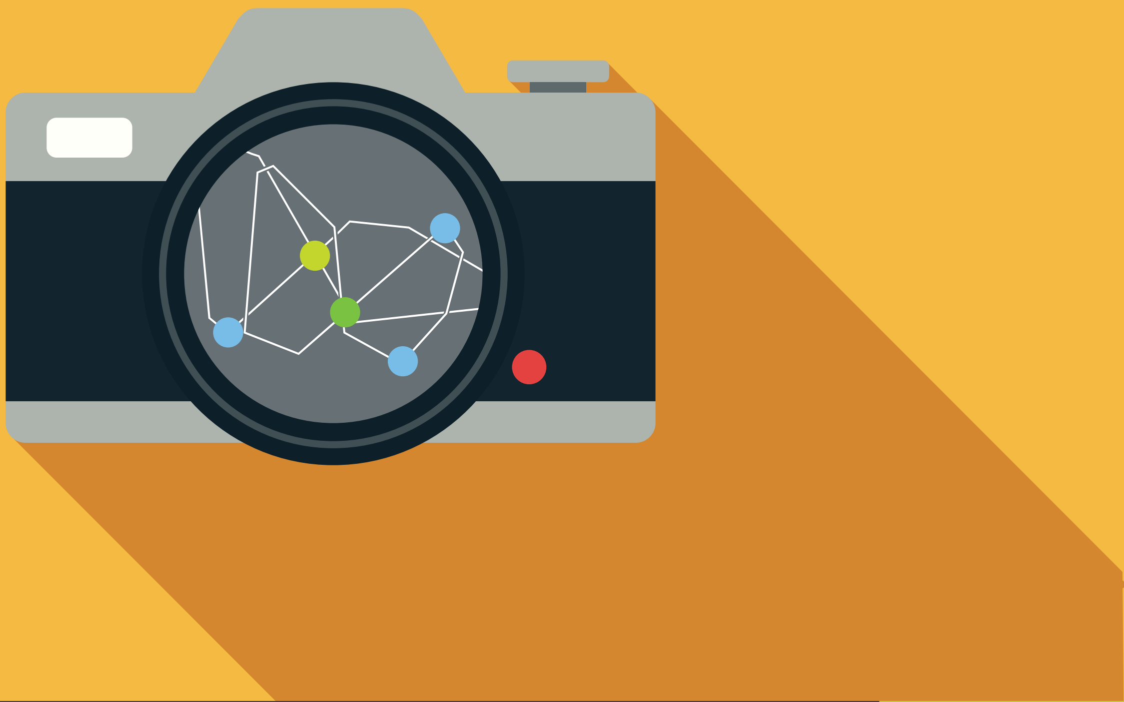

DLTV JOURNAL

4.1

The Journal of Digital Learning and Teaching Victoria

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Digital Learning and Teaching Victoria

Contents

DLTV Journal
The Journal of Digital Learning and Teaching Victoria

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Digital Learning and Teaching Victoria
61 Blyth Street
Brunswick VIC 3056
Australia
Phone: +61 3 9349 3733
Email: office@dltv.vic.edu.au

Invitation to send contributions to
publications@dltv.vic.edu.au

Digital Learning and Teaching Journal is published as a resource for all educators engaged in the effective use of information and communication technologies for teaching and learning.

The editors welcome contributions to the bi-annual issues from classroom teachers and other educators in the form of articles, reports of school-based projects and other reviews. Text and graphic files may be submitted to publicatons@dltv.vic.edu.au

The journal is published by Digital Learning and Teaching Victoria, the new association formed from the merger of the Victorian Information Technology Teachers Association (VITTA) and ICT in Education Victoria (ICTEV).

Editorial

Dr Michael Phillips and Dr Michael Henderson
Faculty of Education, Monash University

Welcome to the first edition of the Journal of Digital Learning and Teaching Victoria for 2017. In four short years, DLTV has become a focal point for Victorian teachers interested in pedagogical uses of digital technologies and this journal provides educators with an opportunity to engage with a variety of professional discussions together with some academic investigations from contributors in Victoria, other Australian states and from around the world.

This edition of the Journal of Digital Learning and Teaching Victoria provides you with a series of snapshots of what is occurring from around the world and the professional development program offered by DLTV allows you to follow up on any areas of interest that may be sparked by articles in this journal and to further enhance your skills and knowledge.

We begin our series of snapshots by looking at robotics with Roland Gesthuizen's effort to bring together 17 of Australia's leading robotics educators. This team of outstanding educators has provided you with an amazingly comprehensive review of 16 robotics platforms that provides you with all the information you need to make a well informed choice about the right robotics platform for your school. We continue our exploration of robotics in classrooms with Gail Marshall's article which provides an international perspective on ways in which robotics can be connected to curriculum for deep and meaningful learning.

Issues of curriculum and technology are further explored in Peter Albion's thoughtful reflection on the history of coding in Queensland schools over the last 40 years. This review leads Peter to conclude that "neither unbridled rapture nor outright rejection would be a sane response to the second coming of coding for all". DLTV's connection with other state organisations is not only reflected in Peter's contribution from Queensland, but also in the work provided by Christopher Chin and colleagues from Tasmania. Their article in this edition of the journal explores the Calculus for Kids project that has introduced 10-12 year olds to calculus and explores developments in higher order thinking.

In addition to robotics, coding and calculus, creativity is another hot topic and Gail Marshall's second article in this edition introduces you to the notion of creativity through making, tinkering and fab-labs. The concept of creative thinking is explored in detail by Romina Jamieson-Proctor and Peter Albion who present their rationale for a theoretical framework for Distributed Creativity in classrooms.

The final article in this edition is by Lisa Wicks who teaches Design and Technology and Information Software Technologies in NSW. Lisa presents the results of a project she developed to explore the possibilities of augmented reality in a Design and Technology classroom. Lisa's work is a fantastic example of how thoughtful design, careful selection of an appropriate technology and a little bit of persistence can result in an outstanding example of pedagogical use of technology to enhance learning.

From robotics to coding, calculus to creativity, from fab-labs to augmented reality, from Victoria to NSW, from Queensland to the United States of America, this edition of the Journal of Digital Learning and Teaching Victoria provides you with a snapshot of contemporary practices and research that we hope provide you with some ideas as to how you might enhance digital learning and teaching in your own school.

From the President

Melinda Cashen

One of the things I love about working in education is the opportunity to reflect at the end of each year. When we finish up for the year in schools it is a great chance to look back on the year that has passed and have an opportunity for celebrating the achievements of 2016. At DLTV we have been doing the same and highlighting the work of our committee and members. 2016 saw the implementation of the new Digital Technologies curriculum and the many professional learning opportunities through face to face events and webinars.

This year DLTV will focus on member resources and our new website with member access will be launched early in 2017. This will see resources for our members including webinars and videos and activities for teaching with Digital Technologies. Our webinars series will continue to support teachers implementing the curriculum for the first time and also build on the great work of Victorian teachers who are already implementing the curriculum.

DLTV developed the VCE resource kit to support the new study design in 2016 and this will continue to be developed through 2017, providing further resources for DLTV members. This will be complimented by a VCE webinar series and forums for VCE teachers.

The annual conference, DigiCon was once again a huge success and showcased the strength of Victorian teachers. With many interstate visitors to the conference it shows how we really are leading the way with Digital Technologies across Australia. The student showcase once again gave hundreds of Victorian students opportunities to experience how digital learning can enrich their lives and showcase digital learning through industries.

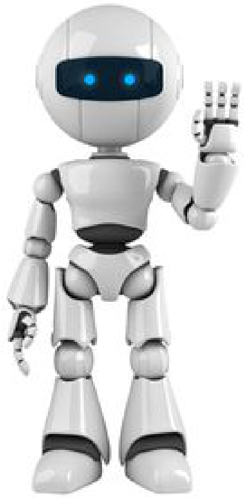
Our DLTV awards this year showcased the great work of members and their schools. Eleni Kyritsis and Gary Bass were the recipients of the awards and have shown tremendous dedication in what they offer in the area of digital learning and teaching. We also awarded a life membership to Nick Reynolds who has been a long standing supporter of DLTV and worked tirelessly over many years to build excellence in digital learning and teaching. On a sad note we also said goodbye to Nathan Jones, a friend to DLTV who had worked alongside many DLTV members with passion and enthusiasm. His loss was felt across the DLTV community.

Once again I would like to thank the editor of our DLTV journal, Michael Phillips, whose dedication to sharing the expertise of the DLTV community is evident in such a high quality journal. To the Committee of Management and DLTV office staff, I would also like to thank them for the hard work and dedication they show to building excellence in Digital Learning across Victoria. Finally to the members of DLTV, I wish to thank you for your enthusiasm, dedication and hard work in building a community of teachers who provide the best experiences for our students in the area of digital learning. We look forward to working with you in 2017.

ROBOTS IN THE 2016 AUSTRALIAN CLASSROOM

More and more robots are appearing in Australian classrooms. This document should guide teachers interested in gaining an overview about robots in the Australian classroom and at what age the technology could be introduced. It isn't the last word or a shopping guide.

It was inspired by response posted to the OzTeachers list by Ken Price to Damien Kee asking what is working well (and perhaps what isn't). It was a labour of collaboration across Australia and is shared on with a creative commons licence.



Edited by
Roland Gesthuizen

CONTRIBUTORS

Roland Gesthuizen	rgesthuizen@gmail.com@rgesthuizen	year 9 & 10 Robotics Mater Christi College & Monash Uni
Ken Price	kenjprice@gmail.com	Curriculum Officer
Peter Whitehouse		
Ivan Dean	oz-teachers@ivandean.com	Year 3 &4, volunteer 5 & 6
Chris Woldhuis	cwoldhuis@nbcs.nsw.edu.au @cwoldhuis	Secondary
Mark Weber	weberscience@gmail.com @numbatmark	Secondary
Simon Brodie	grabman66@gmail.com @simonbrodie1	Primary (yr6)
Carlin Grieve	grieve.carlin.c@edumail.vic.gov.au @carlingrieve	Year 7, 9 & 10
Vickie Vance	v.vance@bth.catholic.edu.au @mrsvsquared	K-12 System Support
Leeanne King	king.leeanne.m@edumail.vic.gov.au	Primary F-6
Michael Graffin	graffin.michael@cathednet.wa.edu.au @mgraffin	Primary PP-6, FLL robotics coach
John Hession	john.hession@dbb.catholic.edu.au	Education Officer: eLearning K-12
Damien Kee	damien@domabotics.com	Domabotics K-12, RoboCupJunior
Nick Jackson	largerama@gmail.com	Senior Leader (various responsibilities) / Y10 Dig Tech class
Geoff McIver	geoff.mciver@dbb.catholic.edu.au	Former Education Officer - eLearning K-12. Used Beebots, Bluebots, Mice, WeDo, NXT, EV3 and Edison with teacher groups & classroom training sessions.
Grant Fitzgerald	gfitzgerald@ceosand.catholic,edu.au @gfitzger62	K-12 System Support
Yvonne Harrison	harrisonyvonne4@gmail.com @yharrison	Deputy Principal Government Primary School, W.A.

WHAT SHOULD I GET FOR MY SCHOOL?

This is a common question yet it really doesn't really matter all that much. In the education realm, we never 'Teach Robotics', instead we use 'Robots to Teach'. Use these platforms to teach programming, computational thinking, problem decomposition, mechanical engineering, branching statements, directional terminology and so on, and so on. The robot itself is just a platform that is used to teach these concepts so it doesn't really matter which one you choose.

The best robotics platform is the one that teacher feels most comfortable using. If they are comfortable with it, then they will teach with it, just like any other tool at their disposal. If the desire is for all students to be involved, then the classroom teacher must feel confident with what they are using. It has to be simple and work every time.

CHOOSING A ROBOTICS PLATFORM

There will be a bunch of factors that will guide teachers in to choosing a platform that suits their school best and they should include;

- **Price.** If there is a robot platform that is amazing, but it costs $5000 / robot, is that a better investment than a great platform that is $200 / robot? For the same amount of money, a cheaper robot can engage more students.
- **Availability:** Are spare parts or add-on easy to source from overseas?
- **Age appropriate Programming Language:** Graphical or Text based? Do you need a platform that can span across both to appeal to a wide range of ages?
- **Curriculum Resources:** Are educational based activities easy to come by? While it would be awesome to have the time to use robots in class because they are fun, in reality everything we do needs to be meeting some parts of the Australian Curriculum. Are those activities affordable/ adaptable / assessable?
- **Teacher support:** Often the 'robotics' teacher/s at a school might be only one or two teachers which makes it a little more difficult to bounce ideas around. Many robotics platforms have good extended Educator communities in the form of mailing lists, forums etc.
- **Professional Development opportunities:** Are your staff comfortable in using the equipment in class. Too often I've seen cupboards of equipment sitting idle in a classroom because the teacher who originally used it has now moved on and no-one else at school knows how to use the gear. Is the equipment easy to use and it is just missing a teacher willing to take it on?
- **Reliability:** If you are spending too much time just getting the platform up and running, then that is time that could have been time spent solving challenges.

THE BIG LIST

BEEBOT / BLUEBOT

https://www.bee-bot.us/bee-bot.html

Simon: We started with these in yr6 but quickly moved them to JP area. This friendly little robot is a perfect tool for teaching sequencing, estimation, problem-solving, and just having fun. They are easy to use and quick to setup. Coding is completed by button presses on device itself.

Michael: We have used these very successfully in PP-2 for developing sequencing skills and an introduction to algorithms (representing instructions using arrows). The beebot resources from Barefoot Computing UK (need to sign up) are brilliant.

Vickie : We have used this as a concrete introduction to computational thinking for Primary teachers as an introduction - non threatening to teachers and can see uses for cross subject use in higher primary years - ie the Australian Money Mat; World Map; Australian Map can be used for challenge tasks at Years 3 - 6 level if they have no prior intro to coding/robotics.

Damien: I love these for Prep-2. They are very user friendly and great for teaching Sequence and directional language. By time you get to Grade 3, they tend to lose a bit of interest as the challenges are usually solved quite quickly.

Ken: BlueBot allows editable stored programs, which makes them more usable for older students.

Yvonne: Our Kindy and Pre-Primary teachers are using these to introduce the idea of how the robot works - in the context of the community map, directional language, counting and the required step sequence. I love the hands on aspect of these robots.

PROBOT

https://www.bee-bot.us/probot.html

Ivan: The Probot is a more advanced version of the BeeBot built as a small car (approximately 30cm in length). The programming options on the Probot are more advanced than the Beebot, for instance, year 6 students quickly discovered they could program the Probot to advance a specific number of centimetres using the inbuilt LCD screen. The Probot can also be programmed using an application from a computer, but I haven't tried that option out yet.

EDISON ROBOT

https://meetedison.com

Roland: Have used with year 9 and 10 Robotics. Good price, especially if you are looking to buy a class set. Novel approach using an audio-optical connection so that it connects any device to an Edison Robot. This can also be used to program using a bar-code reader. Programming interface is free to download and similar to the Lego Mindstorms layout. Seems to be tough but we have had some wheels jam. Can be programmed for basic line tracking. Keep a supply of batteries handy.

Michael: We are roadtesting V1 Edisons in Year 5 this term. The Edware programming language is very complicated, but they are working on Blockly and Python coding tools. v2 is supposed to have fixed the reliability problems with faulty gears and sticky wheels. Cheap, compatible with Lego, but not a huge fan.

Vickie : We have a kit of 15 that travels around to schools on a 5 week loan basis. Teachers have found them easy and from 15, only 2 have been issues. Looking forward to v2.

John: It's early days with Edisons in DBB. We would have 40+ units that have been purchased by schools. We have found that, despite the notice that advises that units manufactured/purchased after a certain date contain the latest firmware, a firmware update is required. Whilst a range of methods for completing this update have been documented, we find that the procedure involved a direct update via the web interface is the easiest. Unfortunately, we have found that this update sometimes needs to be repeated several times after which time the robots operate efficiently. A number of small issues related to correct sound settings for Windows Devices and Chromebooks have been identified with workarounds developed. We have found that the iPad App will not work at all. There is a wide range of pricing difference between various vendors so please shop around.

Nick: So far found the Edisons to be unreliable. Wont scan/ take programs on regular basis. At the moment, they are back with the creators - Microbric to hopefully get them repaired

Geoff: I had laminated some of the supplied barcode sheets and found that the Edison didn't reliably scan. When students hold the Edison and run it over the barcode the reliability improved.

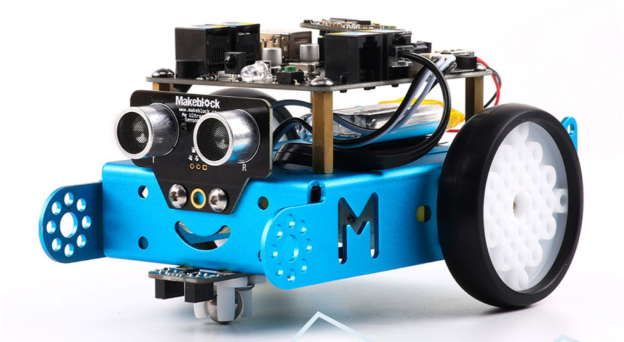
Geoff: I found the Edisons V1 to be a bit challenging with their initial reliability but on updating latest firmware the problems seemed to disappear. Updating firmware using the Chromebook was by far the easiest platform to use. Battery life was a bit of a concern but I have started using Powertech 900mAh rechargeable batteries from Jaycar (@$2.30 each) and I can run an Edison using a Sumo program continuously for over 6 hours. When batteries of any type lose their "oomph", I find the Edison will start to do random things. Putting in charged batteries almost always fixes the problem. Given that one can purchase a set of 10 Edisons for the cost of 1 EV3, the decision on what to purchase can be around ratio of students to robots and whether their use is for integration across the curriculum for whole classes or for extension groups. Certainly the coding concepts are very similar. The improvement with V2 I think will extend the use of Edison's into the secondary curriculum.

Yvonne: Our Department just provided us with a set of 15 which takes our total to 25 V1 robots. My colleague and I used the 10 we purchased during Term 3 with our Year 5 and 6 students in a combined Science/Digital tech project. The bar code lessons were fun and the kids really enjoyed that aspect - we used those to introduce the kids to the idea of a system and why/how this system works. The remainder of the sessions (400 minutes across the term) were taken up with firstly introducing the students to the Edware software and helping them to get the basic idea of programming (we related the loop, if/else and event time aspects to Scratch so that those students who had already used Scratch understood what the yellow icons were all about). Then time was spent on developing an understanding of timing and speed and timing for turns. This proved challenging as did the final activity which involved developing a "map" which related to a specific purpose for which they designed a robot. The design thinking and systems thinking aspect came into play within this particular challenge. The students had a really good go - though some of the Edisons didn't perform well - specifically the wheels not turning was an issue. However, one robot which I had tried to update Firmware using our Windows & laptops and desktops at school was brought out of the stuck cycle once I used my Mac laptop. Not sure why that proved more efficient - it just worked better!

The Edware software was challenging for the students as they thought just pulling the event icons into sequence would work. We will be working on this again next year with our Year 5 and 6 students and hammering the use of variables within each event so that their programs work. Also thinking of taking these down to Years 3 and 4. Year 3 will use the barcodes and we will discuss systems and how they work as well as continuing their programming mathematical shapes with Turtle Blocks. The Year 4's we will do the barcodes and then the first 5 lessons with Edware like we did this year with our Year 5 and 6 students. Plan is to strategically have these in place in Years 3 and 4 and move on to something else in Years 5 and 6.

MBOT

http://www.makeblock.com/mbot



Roland: Have used these with year 9 and 10 Robotics. Very easy to assemble, keep an eye on regularly tightening the screws. Assembled Robot fits nicely back into the original box. Tricky coding the first time. Many sensors including line tracking, collision detection, Infrared communication, etc. Remember to start with the mBlock software, install the arduino driver, then attach USB lead. mBlock software permits programming with a drag-and-drop block interface but it also permits directly coding the arduino chip.

Michael: I love the mBots! I bought a mBot and MBot Ranger for my gifted Year 5 coders. Makeblock are working on developing online tutorials, which you really need to read to get your head around how to program them. Highly recommended for coding extension from late Year 5 up. They are harder to program than EV3 Mindstorms. Price range around $140-230 depending on model.

Carlin: These are used as an introduction to robotics for all students at Year 7 level. We have 13 which makes a class set (1 between 2). This allows a class set, which made it achievable in terms of cost, but students responded extremely well to the collaborative learning. With a small amount of initial scaffolding (Specifically how Scratch/individual blocks work) students are able to assemble code for small tasks. Within the first lesson (72 mins), Students are able to connect, program and control an mBot using the arrow keys on the keyboard, turn on flashing lights, and have a basic siren sound. Differentiated Learning is also easily managed, as students complete at their own pace, completing a variety of activities that can include make an automatic xylophone player or even building a 3D Printer with this ecosystem

Promo Video: https://www.youtube.com/watch?v=-hQtdYd5i-Y

Programming Examples*:
http://learn.makeblock.com/en/mbot-programming/

*These coding examples would be at the end, just prior to assessment (Except music example)

Learning Path: to provide the skills and knowledge needed for VCE Computing.

Year 7	mBot	Drag & Drop Coding Allows for Direct Arduino coding for extension
Year 9	mBot / Arduino	Combination, ensures that the transfer occurs Similarities & Differences highlighted. Basic Projects
Year 10	Arduino / Unity 3D	Coding via Arduino C or elective C# (Unity3D)
VCE	C# Programming	Probable base language

LEGO MINDSTORMS (EV3/NXT/RCX)

Chris W: **RoboCup Junior** is an awesome resource for those wanting an excellent place to start and to continue down the path of structured learning where students are driving the learning and pushing the boundaries. It is a very easy path to start down (resource packs are available from **MTA** - they cost a lot of money, but are not expensive as they last a long time and very reusable).

Chris W: We have had a long experience with RoboCup, and then linking to **World Robot Olympiad** to expand students' horizons in many areas. The competition is strong, but also very collegial and supportive. It is a growing community of learners.

Chris W: We are starting to use some of the older Lego devices (NXT and even trying to get the old Yellow bricks working) as the brains behind simple controlled or controllable devices. Eg Camera sliders, camera following device, controlling an old electric wheelchair. Sometimes linked to remote control gear.

MIchael: The LEGO EV3 can be used from Year 5 up. We currently have five for our FIRST LEGO League robotics teams. FLL is a fantastic competition to be a part of, but it is a lot harder than RoboCup Junior! Highly recommended, but pricey!

Vickie : We have 5 EV3s that form part of a loan kit that is borrowed by schools. We find they lend themselves, as Michael suggests, to Year 5 onwards, and as a second stage - currently using Edisons as the step between these and BeeBots/We Dos.

Damien: I've been using these for 15 years now and I still love them. The construction element to them really ties into the STEM ideas, but if you are only interested in 'programming' there are other cheaper options. That being said, they are an extremely robust platform and I have robots that are 10 years old and still going strong. You can program in Graphical or Text based languages making them suitable for a wide range of age groups. I teach with them down to Grade 3/4 and all the way up to Grade 12 and beyond (university level). The datalogging aspect is an added bonus allowing the platform to be used for Science as well as Technologies.

There are plenty of resources available and the learning curve to get up and running is very easy. These would be my pick for a robotics platform that can cover a variety of age groups and subjects.

Yvonne: Would love to use our old RCX bricks but I need to find a way that will work. Thought about the EV3 software but people tell me it's not compatible. Used to use the RCX's for Robocup from around 2003-2009 with Year 4-7 Talented and Gifted students for an extension program. Can't afford to upgrade.

vide the skills and knowledge needed for VCE Computing.

LEGO WEDO 2.0

https://education.lego.com/wedo-2

Michael: We are testing the 2nd generation of these kits in Year 5, programming them with Scratch. It is a bit tricky to get it connected, but well worth it. We will program the robots on iPads in Year 2 and 3, and then with Scratch in Year 4. They are much simpler than EV3, and I'm looking forward to learning more next year.

Tip: To get Australian Curriculum Pack on iPad, you need to change the language settings to English- Australia.

Home page https://education.lego.com/wedo-2

Damien: Even though you cannot buy them anymore, I continue to use version 1.0 in class. I use it at a grade 3 and 4 level and the software is very easy for students to pick up. There are plenty of good activities and support for teachers available.

Yvonne: I'm interested in these! Apparently One Education sold the kits as they used to connect WeDo to the XO Duos with Scratch - don't know if that will work now. Would love to know if anyone has experience with this.

VEX IQ

http://www.vexrobotics.com/vexiq/

Roland: Seen used by **http://DATTAVic.edu.au** with Victorian secondary students. Perhaps more for challenges

Damien: The VEX IQ platform is relatively new to Australia but has a big following in the US. Similar to LEGO, it is a modular building system which means you can use the elements to build countless different types of robots. The controller is fantastic, with 12 ports that can be configured as either input or output. The sensors and motors are easy to work into your system which makes building quite easy. Software is available in either Graphical or Text based allowing it to be used in a wide range of classes. The IQ system also comes with a remote control unit, which means it is easy to have things working quickly if you want to focus more on the 'Engineering' side of things instead of 'Programming'. Availability in Australia is limited but no doubt will become more accessible in time. I've seen them used from grade 7 and above.

OZOBOTS

http://ozobot.com/

Grant: I have used Ozobots and really like them. I find they are useful as you move from a line following robot, with the students creating the tracks, to drawing codes and then moving into the programming side - with

http://ozoblockly.com/editor. The way the program transfers the code to the Ozobot is amazing - just place the Ozobot on the screen and click ***load***. The screen flashes and the Ozobot gets the program!

There are also apps for the Ozobots on iOS and I presume Android, although I haven't used them on Android.

They are really flexible to use. I have targeted them at Grade 3 and 4, but used them equally as well with 5 and 6.

Good price for 6 robots (with some extras) - about AU$550.

Yvonne: I will be looking at these for Year 1 and 2 students as I think patterning and systems thinking can be developed through firstly using the coloured lines and then gradually introducing them to block coding.

PROGRAMMABLE MINIDRONES AND DROIDS

Ken: A series of affordable drones and related devices has been developed to be programmed through the Tickle app **https://tickleapp.com/** for iOS (iPads). This is a comprehensive programming environment which adapts to the selected hardware (and also allows programming with no specific device selected) The supported hardware is listed at **https://tickleapp.com/devices/** and includes various devices from Parrot and devices like Sphero, LEGO WeDo, Dot, Ollie, BlueBean etc. We've successfully used the Parrot Rolling Spider and Hydrofoil. The Rolling Spider is very suited to classroom environments, including collisions. The Hydrofoil is a boat powered by a drone that can be detached and used on its own.

SPHERO / OLLIE

http://www.sphero.com

Ivan:The Sphero is very engaging for students as it can move quite quickly, has a bright RGB (programmable, colour changing) LED inside it and is of course reminiscent of BB8 from the new Star Wars movies. The Sphero includes an accelerometer so it can detect running into obstacles or falling off drops. The Sphero typically costs $AUD200.

Roland: Water proof, totally sealed and robust. It is worth looking up how to reboot and factory reset these devices, not intuitive but easy to do and listed on the website. The bluetooth name gives a clue about the flashing colour of each sphero. Very fun for younger kids. If you are buying one, get the transparent SPRK+ or education version. Consider customising by 3DPrinting a chariot.

Make sure you get the SPRK+ edition as it has some subtle advantages and comes recommended for classroom use, for instance, a transparent shell so you can see how it works, and also information in the box for getting started with classroom activities. A variety of apps allow students to engage in different ways, including:

- Simple remote control, change light colour & mode, etc.
- Drag & drop style programming using Tickle
- Code using "Oval", a Javascript like language using the provided apps (Oval can also be displayed next to your blocks of code to guide students into the language)

There are many resources around using the Sphero in classrooms, especially year 5&6,
e.g. this YouTube video from the United States provides some examples:

https://www.youtube.com/watch?v=0yQYr7CIxBc

Here is just one good example of the sort of information that can easily be found by Googling "Sphero challenges" (meaning challenges for students to undertake, not problems working with Sphero robots!) http://www.coolcatteacher.com/super-sphero-teaching-methods/

Yvonne: We have been provided with three of these by the Department. I'm looking at the SPRK Lab software and thinking probably useful in a design/digital tech context for trying out some kind of challenge relating to theme parks or something like that. There are so many blocks of code and some of them are beyond the comprehension of the younger students - I see this as another robot for older students who have a knowledge of coding.

DASH AND DOT

https://www.makewonder.com/dash

Dash is a robot, charged and ready to play out of the box. It responds to voice, navigating objects, dancing, and singing, You can use Wonder, Blockly, and other apps to create new behaviors for Dash.

Damien: These guys have so much personality and really engaging for kids. They have 'personality' built in so that as soon as you turn them on, they look around and act like curious little kids. You can drive them around from a tablet app which is a great way to introduce them to kids before moving on to the programming. Programming is done through the Blockly App which is very similar to Scratch which makes it easy to introduce to kids. There are a good range of sensors built in which allows for programming for lots of different behaviours. Best use in the Grade 2-7 age group.

There are lots of teacher resources available on the website.

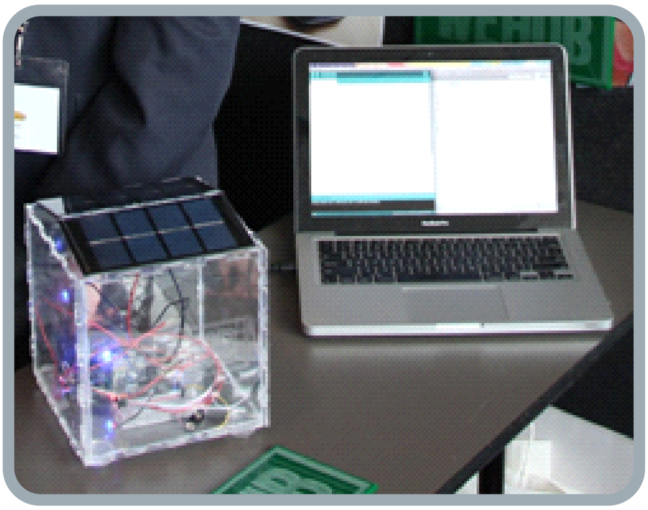
Yvonne: Strategically I'm thinking Year 1-2 as the Department also supplied us with iPads loaded with apps. I'll be looking for an App that is similar to Kodable or Scratch Junior to drive Dash and Dot as they are the apps our Kindy and Pre-Primary students will be familiar with. I can see lots of scope for cross-curricular projects with these robots.

FINCH ROBOT

http://finchrobot.com

Roland: Similar to the robots that can be built using the Hummingbird Robotics kits. Requires a permanently connected USB interface with the computer. Provision for adding a pen to the back of the robot. Some sensory monitoring for collision avoidance, LED, motor and sound controls, Interesting controller using an Arduino board that can be programmed directly or flipped over and programmed using the drag-and-drop Birdbrain software.

ARDUINO (RAW)



Chris W: Much of our experience in robotics other than Lego has been through our Student Opportunities Week program called "Hi Tech Toys" (think Outdoor Education with student choice). During this time students choose their high tech project, many choose Lego, but we have encouraged the use of Arduino, and some of the more adventurous have chosen to design and start to build a robot of some kind. Some of them are more applications, and less robotics. E.g. WeHub - Remote Weather Station) - Arduinio based with weather measuring sensors and Bluetooth updates, made from laser cut acrylic.

Chris W: Others have been more about control and interaction. Some examples are:

Wifi controlled robot: An Arduino based vehicle that is controllable via wifi. The theory was wifi allows control of the robot from anywhere in the world or universe.

FireDrone 3000 - Modified Parrot AR Drone for fire monitoring purposes. A mini Arduino mounted on the drone to simulate monitoring of back burning operations.

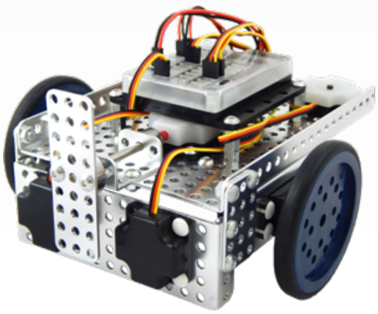
ARDUINO (DEAL EXTREME, EBAY)

Mark: Another approach is to build the robot from the ground up. As Seymour Papert put it, "hard fun". This kit can be purchased from around $aus10 off Ebay. The students can then add Arduino, sensors and actuators to make line followers etc. We found we needed extra power so replaced 4 AA battery pack with 6. You also need a switch to turn off and on. But for $10 plus say another $15 for incidentals, a perfect, low cost solution. Incidental teaching involved the Arduino IDE, soldering, using a screwdriver and problem solving. We had a couple of girls turn up to just learn these skills.

After a while, some students independently went down to manual arts and learned how to use CAD software and the laser cutter. The arrival of a 3D printer also generated some excitement. This robot fits in nicely to a makerspace approach and involves reals STEM.

ARDUINO VARIANT

Modern Robotics http://modernroboticsinc.com/



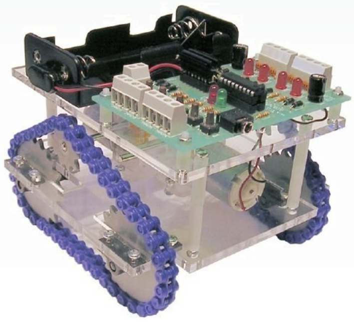
Ken: One product is the **Spartan robot**, based on an Arduino controller and a well-engineered aluminium frame machined with a matrix of holes that are compatible with a well-known metal toy building system.

The Spartan has proprietary sensors, switches and motor modules, which is both a plus (assembly is easy) and a minus (not easy to add cheap sensors, expensive, single source).

Tasmania has received a generous donation of a large number of these robots. A block-based coding environment (ModKIt) is under development by the parent company but is (at time of writing) incomplete - in particular it has no Save facility and has "blocks" written for a small number of input and output devices. This limits the current use of the graphical coding environment. It can still be coded in Arduino as normal.

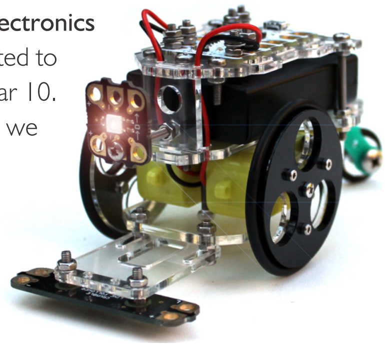
LASER CUT IT YOURSELF TANK KIT

Available from **Kitronik** in the UK. Mark: Just started to build these today with year 10. Will provide more info as we progress.



CRUMBLE ROBOTIC VEHICLE

Available from **Redfernelectronics** in the UK. Mark: Just started to build these today with year 10. Will provide more info as we progress. Very cheap.



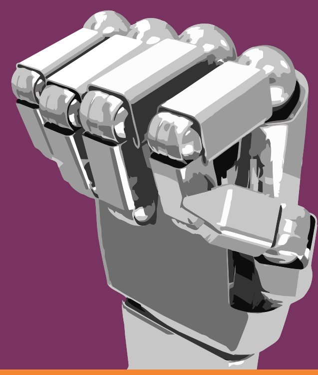
Feature Summary Table

	Blue Tooth DL	Water proof	Scratch friendly	Block coding	Touch	Light	Sound	Distance (IR & US)
BeeBot								
BlueBot	X			X				
ProBot								
Edison Robot (Python version online)				X	X	X	X	X
mBot			X			X	X	X
LEGO Mondstorms	X			X	X	X	X	X
LEGO WeDo 2.0	X		X	X	X		X	X
VEX IQ	X							
Programmable minidrones droids								
Sphero/Ollie		X						
Ozobot (also line following)	X			X				
Dash & Dot	X			X		X	X	X
Finch Robot								
Arduino (raw)	Possible				X	X	X	X
Arduino (Deal Extreme)								
Arduino variant								

Recommended Age Group Table

	P-1-2	3-4	5-6	7-8	9-10	11-12
BeeBot	X	X				
BlueBot	X	X				
ProBot		X				
Edison Robot (Python version online)		X	X	X	X	
mBot			X	X	X	X
LEGO Mondstorms		O	X	X	X	X
LEGO WeDo 2.0		X	X			
VEX IQ			X	X	X	X
Programmable minidrones droids			X	X	X	
Sphero/Ollie			X	X	X	
Ozobot		X	X			
Dash & Dot		X	X			
Finch Robot			X	X	X	
Arduino (raw)				X	X	X
Arduino (Deal Extreme)				X	X	X
Arduino variant				X	X	X
Laser Cut it Yourself Tank Kit			X	X	X	
Crumble Robotic Vehicle			X	X	X	

Robotics Revolution



THE ROLE OF ROBOTICS IN CONNECTING CURRICULUM TO DEEP, MEANINGFUL LEARNING.

Gail Marshall

Gail Marshall is a writer and editor for The Fresno Bee, a major metropolitan newspaper in California. She also owns and operates a freelance business, Marshall Arts Communications Consultants.

The biggest thoughts often come from the littlest people.

A Canadian second grader had just spent an hour or so coding with his classmates when the child was asked a simple question: "What have you learned?"

"Today taught me that anything is possible," the child said. "I kept wanting to give up when I couldn't make the computer do what I wanted, but I kept on trying and having a growth mindset. When I couldn't get it, I asked a friend, and we realized that two brains are better than one."

That little gem is the kind of comment exciting Kerry Zinkiewich, an innovations consultant at Kawartha Pine Ridge District School Board in Peterborough, Ontario, Canada. She's found that if you want to get a close-up view of the progress in teaching robotics and coding around the world, start with these "littles."

From a primary schooler's sense of wonder to high school students building a prosthetic hand for the disabled in Clovis, California, robotics and coding education over the past five years is igniting worldwide interest as teachers gain expertise and new products make it possible for teens and college students to improve the world right in their classrooms. Plus, it's super fun!

Engagement and brain business

Kindergarten students in Zinkiewich's district are enchanted with a little critter called Bee-Bot in their classroom. As the children learn to program this floor robot to do things that make them giggle, they also are doing serious brain business, like learning direction, location and procedural writing.

And the educators are having just as much fun. One particularly delightful day for Zinkiewich involved a field trip to a local high school, where innovative primary school teachers teamed up with high school counterparts. Eleventh grade students were trained to teach the kindergartners how to program Lego Mindstorm robots.

"To say the day was a success is an understatement," Zinkiewich says. "All the kids, young and old, had a blast."

It is a very good day when school is fun, but job one for all teachers and learners is to connect that fun with the fundamentals of the curriculum. Where, exactly, do coding and robotics fit into what schools are charged with teaching?

Here is a start: Robotics students and teachers are making connections in math to spatial sense, patterning and the problem-solving, reasoning and proving process. In social studies, there are connections to mapping, and in language to reading a new language and procedural writing.

"Teachers are starting to see how different robotics kits like Lego Mindstorm, Lego WeDo and Vex can not only grab student attention but also help them learn concepts required from the curriculum in deep, meaningful ways," Zinkiewich says.

One seventh grade classroom used the Vex IQ kits to reinforce the Cartesian Plane by having students program the robots to move to various locations along the X and Y axis. In primary classrooms, students use the Lego WeDo kits to explore various ways machines move, and to link the characters they build and program to story writing.

Zinkiewich also is excited by the creative way teachers are approaching the curriculum. It is no longer a series of skills to check off.

"If we truly want our students to learn deeply, we need to consider the curriculum differently and bring students' interests and questions into the planning process. Robotics and coding supports that happening."

Real-world applications

This year, Zinkiewich has made it a point to talk to many different people in the world outside of education who use coding and robotics in their real lives. One coder wishes that people applying to work with him knew how to think and problem solve. He finds that many people can write code but have no idea what to do when there is a problem.

"This is what coding and robotics teaches our students," she says. In the future, "we have no idea about the types of jobs that our students will be performing. However, we do know that there are some skills that will be needed."

Canadian educational researcher and consultant Michael Fullan calls these the six Cs: character education, citizenship, communication, critical thinking and problem-solving, collaboration and creativity. Coding and robotics develop all of these, educators say.

"Of course, they won't all be addressed without careful planning of tasks by teachers," Zinkiewich notes.

From struggler to scientist

Technology teacher and ISTE member Trevor Takayama of Amherst, Massachusetts, watched a sixth grade student he calls "J" go from a struggler to a scientist in just a few weeks.

J had an aide every day because learning in the classroom was such a hardship for him. There was one exception—he loved technology class. If only, the young boy wished out loud, this exciting time could be more than just 40 minutes once a week.

One day, during an elective makerspace time with Takayama, he built a fully functioning robot from only a few parts with a Lego EV3 kit in one class. He asked Takayama to please save it for him until next time.

The following week, his teacher gave J his own iPad mini and demonstrated how to use the Lego Commander app to connect to and control his robot—which the child named "Bob". When the next two classes met, J was no longer the struggler but the center of positive attention from his classmates on his "awesome creation" as he drove the robot down the hallway.

J is one of Takayama's favorite success stories.

"When students free build or free play with robots, you can really see them being scientists," Takayama says. "They love to test things out, push the boundaries of the programming and try out the cool new toys. It's fascinating to see what they can come up with; each student does something different, and teachers usually learn a thing or two from them."

Takayama has been working as a technology teacher for five years in California and Massachusetts. He loves working as a specialist because he gets to teach students how to code, control robots, create presentations and become Google masters.

He's observed many secondary learning skills his students at Fort River Elementary School have acquired using robotics. For instance, they learn to read directions, follow directions and troubleshoot when the diagrams don't make sense.

Robotics kits mean "they often build in groups," he says, "which helps build their communication and teamwork skills. It is amazing how caring, helpful and kind they can be when they work together. Adults can learn a lot from them!"

Oh, and for J, this was not temporary success. "At the end of the year, he told me that technology class was his favorite part of school, and he wished that he could spend the whole time in school building robots."

Get real with students

Mark Gura, ISTE member and author of *Getting Started with Lego Robotics and Make, Learn, Succeed* published by ISTE, was an early adopter.

Robotics, Gura says, is a perfect example of showing students how they will live and work in the world they will encounter as graduates.

"The whole point of student robots and programming them is for kids to see that there are ways for humans to talk to machines and to instruct those machines to do the things we want," Gura says. "Further, to see robots as machines that we create to solve our problems."

It is very much about applied student creativity, and therefore, he believes, it is one of the most relevant things educators can offer.

Gura got started in robotics as a way to play and discover with kids after school. And he highly recommends that strategy as a starting point.

As a curriculum coordinator for a group of middle schools in New York City, he purchased some Lego Mindstorm kits, and then sat with a few teachers and students for a couple of after-school sessions just playing and experimenting, sharing their discoveries and fun.

“Later on,” he says, “we sought more formal, precise understandings, but this was a great way to start. Playing alongside the kids to figure things out was one of the best examples of how technology redefines learning roles and processes I've ever witnessed.”

But the rapidly exploding marketplace for robotics teaching tools can be a bit intimidating. His advice for beginners? In essence, there are three varieties of robotics materials for students:

- Robots that are already whole and functional. The challenge is for students to program them to do things. This involves programming and writing code.
- Lego Mindstorm (including NXT, EV3, etc.) and WeDo robotics kits. These call on kids to design and build a robot for a specific function and then program and test its performance. He sees value in both options, although he is particularly taken with what he calls the 'end-to-end' variety that has been so wonderfully explored and made available to kids by Lego.”
- Robots built using generic parts like the low-cost Arduino and Raspberry Pi processors.

“I find Bird Brain Technologies' Hummingbird Robotics Kit intriguing because it encourages kids to see the expressive side of robots as they work on the technical and functional aspects of making what I see as kinetic sculpture perform in unique and artistic ways.

“In my mind, this offers kids so much, both the creative possibilities of visual art and of robotics, in the same project. Wonderful!” Gura sums up.

It's all about the base: computer science

Hadi Partovi, founder of code.org, completely understands the fascination withrobotics. He's a big fan, too. Perhaps you saw him hanging out with R2D2 at ISTE 2016 in Denver?

However, Partovi has a big message of his own. Behind every great robot is one critical thing: computer science, perhaps the most neglected academic necessity in our schools today.

Check out code.org and you'll see a vigorous campaign to make computer science classes available to every child in every school in America. Site visitors get an opportunity to make that happen in every community, and there is a petition to sign, pledging support for the effort. Hundreds of thousands of people are on board.

His statistics are pretty startling if you are listening to the presidential political discussions, as we all are, that focus on the need to multiply the job opportunities in our country:

- Computer science drives innovation throughout the U.S. economy, but it remains marginalized throughout K-12 education. Only 32 states allow students to count computer science courses toward high school graduation.
- There are currently more than 500,000 open computing jobs nationwide. Last year, only 42,969 computer science students graduated into the workforce.

Those jobs are just sitting there, waiting for our students to be trained to snap them up. Did we mention that these jobs can pay 40 percent more than the salary of the average college grad?

Partovi, his colleagues and partners are pushing for computer science to be part of all core classes in high schools, right along with algebra and biology. A huge part of his mission is to encourage more girls and students of color to jump aboard this great opportunity also.

This fall, 500 U.S. high schools are launching AP computer science classes in a partnership with code.org, the College Board, National Science Foundation and TEALS, which stands for Technology Education and Literacy in Schools, among other partners.

“In this day and age, computer science is no longer just *vocational* for getting a job,” Partovi says in his popular TED Talk. “In this day and age, computer science is completely *foundational* for any job you may want to have in the next 20 to 30 years.”

It should not be this hard.

Research shows computer science is in the top three most popular academic interests of high school students, just under subjects like art and design. Code.org's research shows 90 percent of parents in the U.S. want their children trained in computer science, yet many schools are still striving to meet the need and demand.

If this is the Second Coming of Coding

Will There Be Rapture or Rejection?

Peter R. Albion

University of Southern Queensland, Toowoomba

Coding made the national headlines in 2015 and appears to have garnered sufficient support from politicians to be seen as an essential component of education for all. Educators with longer memories will recognise that this is not the first but the second coming of coding for all as a focus of education in technologies. The first coming ended in rejection because too few teachers really understood the potential. The immediate response to the second coming appears to be rapture but it could easily end in rejection. How do we develop a sane response to the current impetus for coding and sustain it? The answer lies in preparing teachers with sufficient knowledge of coding and computational thinking for it to be authentically useful in their own lives. Only then will they appreciate its value for learners in their classrooms.

Introduction

Coding made it into the national headlines in 2015 when Federal Opposition Leader, Bill Shorten, asked then Prime Minister, Tony Abbott, whether he would "support coding being taught in every primary and secondary school." The then Prime Minister initially derided the idea with a comment about kids going to work as coders at age 11 but later confirmed that the Government was already supporting the concept in the national curriculum (Bagshaw, 2015). A few months later, the Queensland Government launched Advancing Education, described as an action plan for education in Queensland and featuring coding as a key component marked by the hashtag –

#codingcounts (DET, 2015a). The website noted the highlights of Advancing Education as fast-tracking of the Digital

Technologies subject from the new *Australian Curriculum: Technologies* (ACARA, 2015) beginning in 2016, creation of a coding academy, and incubation of future entrepreneurs. Robotics was proposed as a key component and professional development was to be provided for teachers. These moves are part of a wider embrace of STEM (Science, Technology, Engineering, and Mathematics) education as critical to our national future.

Although 'coding' has appeared more often in political discourse, the *Australian Curriculum: Technologies* (ACARA, 2015) uses 'program' or 'programming' as frequently as it does 'code' or 'coding' when referring to the techniques used to control digital technologies. Among those who work with digital technologies, 'programming' is understood to refer to the activities involved in specifying the logic involved in the solutions to problems whereas 'coding' refers to the process of expressing that logic using a language appropriate to the task and the technologies in use. A recent European report about programming and coding in school curricula (Balanskat & Engelhardt, 2015) acknowledged that coding can be viewed as a subtask of programming in which an algorithm is expressed in a target programming language but opted to use the terms interchangeably in the report. The same report also acknowledged the importance of 'computational thinking' (Wing, 2006) which is one of the key ideas in the *Australian Curriculum: Technologies* and a starting point for being "more effective in an increasingly computed society" (Booch, 2014, p. 11). Computational thinking, programming and coding are related ideas and all are important for the process of solving problems and expressing the solutions in digital technologies. Perhaps because of its role in expressing ideas in a language similarly to general literacy, coding has become most visible in public discourse about education.

Various opinions have been expressed about coding in Australian schools in the past year or two. In close proximity to a call by the Prime Minister for improved teaching of STEM subjects, especially coding, outgoing Chief Scientist of Australia, Ian Chubb, suggested that primary teachers graduating from teacher education programs are not sufficiently well prepared to teach coding (Dodd, 2015). As remedies he suggested "attracting higher quality students into primary teaching courses, boosting science, technology and maths courses in teaching training, improving professional development and putting specialist STEM teachers into schools to mentor others." Effective as these might be in the medium to long term if they could be funded and managed, they are not short term solutions.

Recent University of Southern Queensland graduate, Elke Schneider, has blogged about her experiences with teaching digital technologies. She was enthusiastic about the recognition of the importance of digital technologies but expressed misgivings about how the push for teaching coding could be implemented, noting that many teachers were concerned about learning to code themselves before attempting to teach it. She questioned whether pushing coding into schools without adequately preparing teachers might turn kids off rather than on (Schneider, 2015).

On the World Bank site, Michael Trucano described initiatives in Europe and elsewhere to introduce coding into classrooms and cited the aforementioned European report (Balanskat & Engelhardt, 2015) highlighting some of the related pedagogical challenges as well as the challenges of professional development for teachers. He listed arguments commonly made for coding, including future employment and development of logic and problem- solving skills. He concluded by suggesting that we should be thinking at least as much about coding to learn as learning to code, arguing for the place of coding across the curriculum where it can be applied in support of varied topics (Trocano, 2015).

Elsewhere, the Chief Scientist has noted that, instead of 'future-proofing', humanity would be better served by 'future-priming', through developing the capabilities needed to benefit from technological change (Chubb, 2015). Those comments were made in the context of launching a report that argued that all Australians, not just those destined for careers in STEM specialisations, require sufficient knowledge of STEM to engage in related debates and decision making (Williamson, Raghnaill, Douglas, & Sanchez, 2015). As presented in the *Australian Curriculum: Technologies*, which includes computational thinking among its key ideas and explicitly mentions coding in its content descriptions, and in the Queensland Government initiatives, STEM education inevitably includes coding and teachers will be required to learn and teach it.

There is no doubt that STEM education and coding as an element of the new *Australian Curriculum: Technologies* (ACARA, 2015) are hot topics in Australia and more widely. As has been noted above, there are varying opinions about why coding should be taught and learned in schools. There are also doubts about the capability of teachers to teach it, at least without extensive professional development. Hence there are good reasons to think carefully about the issues. This paper attempts to recall some of the past history of coding in schools and to consider what lessons might be learned from that history.

A short history of coding in Queensland schools

Those few teachers who have been around computing in schools since the 1980s will recognise that this surge of interest in coding for all in classrooms is at least its second coming. It may be useful to recall some of that history for the benefit of those too young to remember it.

Coding appeared in Queensland secondary school classrooms when computing was first included as an option for study in the mathematics curricula of the mid-1970s but, for the first several years at least, few schools had direct access to computers so the process of learning to code was slow. If schools elected to teach programming, the common approach was for students to code their simple programs on mark sense or punch cards and send those to a computer centre to be executed and the printed output returned. For rural schools that required the cards to be sent by bus or post to Brisbane State High School for execution. The cycle from recording code on cards until the printed output was returned required 3 days to a week. If there was an error in the code, then correcting it and obtaining new output required another cycle of several days.

Such a long cycle was untenable for teaching because it allowed limited scope for development of more complex programs through practice and left long periods in classes to be filled with more theoretical activities that were less motivating to many students. It was not long before schools began to adopt the early programmable calculators that were becoming available around that time. Despite limitations for data entry and storage and the absence of standard programming languages, it was possible to develop programs using the standard algorithmic structures of sequence, selection and iteration. The opportunity to rapidly plan, code and test solutions within the space of a single lesson in a classroom rather than waiting days for output was more motivational for all and allowed development of more complex programs within the space of a semester.

The next major advance was the appearance of the first personal computers in schools in the late 1970s. The Apple][, Commodore PET, Tandy TRS80, and Ohio Scientific were among the first computers to find their way into schools. Because there was very little commercial software available in those first years, the major application for microcomputers in schools was for programming in the mathematics curriculum. For the first few years of the 1980s the number of microcomputers in Queensland schools was few enough that the Department of Education was able to produce a brief annual report that detailed the microcomputers in schools across Queensland and their uses.

The first coming of coding for all

Although the Logo computing language was created in 1967 and was used experimentally in schools from that time, its popularisation followed the emergence of personal computers in the late 1970s (Logo Foundation, 2015). A version was created for the Apple][computer at that time. Following publication of *Mindstorms: Children, Computers, and Powerful Ideas* (Papert, 1980), Logo became more widely known. By the mid-1980s, as computers became more widely available in Queensland schools, there were professional development activities across the state to introduce teachers to programming with Logo with the expectation that it would be widely adopted in schools at all levels.

Papert (1980) described scenarios in which computers, using behaviourist principles embodied in programmed instruction, would be used to teach children. He regarded that approach as undesirable and noted that one of the best ways to clarify our understanding of something is to explain it to somebody else. Hence, he argued that it would be preferable for children to teach the computer rather than be taught by it. That is, the process of analysing some process and expressing it in instructions for a computer would be an excellent way of clarifying and demonstrating understanding.

The utility of teaching as a path to learning is evident to anybody who has ever tried to explain something of even moderate complexity to somebody with only a limited grasp of the necessary mental building blocks. Teachers, parents, sports coaches, and students working together in study groups are all familiar with how trying to explain something to somebody else works to clarify understanding for the explainer at least as much as the explainee. A computer is the ultimate patient learner and the process of deconstructing some process and expressing it in the limited vocabulary of a programming language is an excellent way to clarify understanding.

Papert's own educational views, developed during his earlier work with Piaget, favoured a constructivist approach in which children would learn from experience. He pointed to the way in which children learn language and other common knowledge through being immersed in the world and recounted his own experience of learning about ratio through an early fascination with systems of gears. Based on his observation and experience Papert argued that, just as children learn English or another language by living in a world where that language is spoken, the best way for children to learn mathematics would be to be in 'mathland'. He developed the idea of microworlds, simplified but realistic representations of some system, for learning through experience and extended the ideas of constructivism into constructionism in which learning is demonstrated by constructing and sharing some artefact (Papert, 1980).

The Logo computer programming language was developed specifically for education. It was designed to be easily accessible at a basic level so that young children could quickly learn the rudiments but rich enough to support more advanced programming. It was used successfully with very young children and to teach university computer science courses (Logo Foundation, 2015). Early in the history of Logo, Papert's group devised and popularized the 'turtle' which was originally a robotic device that could be driven around on the floor under computer control and was capable of raising and lowering a pen to trace its path. Instructing the turtle to move so as to trace out particular patterns helped make simple programming concepts concrete and provided a microworld in which learning geometrical concepts of distance and angle was a natural consequence of trying to program the turtle to achieve some tangible movement goal. The mechanical turtle was expensive so most implementations of Logo in classrooms were restricted to using the same instructions to drive a 'turtle' around a computer screen. The 'screen turtle' was the most common experience of Logo for most teachers and children.

Logo continued to be developed and extended in various versions though the 1980s and 1990s. There were multiple versions of the language with graphic and other extensions, including interfaces to support control of Lego and other systems. Nevertheless, within a decade or so Logo had all but disappeared from most school classrooms. There were a few schools, including some of the early adopters of laptop programs, that made versions of Logo a feature for a time but, as computers became more common in business and homes, the focus of computing in schools mostly shifted to standard office applications and the World Wide Web.

Implementation of Logo in school classrooms attracted research interest that demonstrated benefits for learning, especially in mathematics (Clements, 1987; Kurland & Pea, 1985; Hoyles & Sutherland, 1987). There seems to be no definitive explanation for the disappearance of Logo from most classrooms despite the apparent benefits for learning. Very likely the reason was that typical classroom applications seldom progressed beyond drawing simple geometric shapes on the screen or producing short animations. The likely cause of that may well have been that few teachers had any real concept of what else might be possible with the tools at their disposal. The first coming of coding for all in the general school classroom concluded almost as quickly as it had begun.

The second coming of coding for all

Programming continued and expanded in schools over the past couple of decades but that activity was very largely in secondary schools and, with few exceptions, involved a specialised subject taken by a minority of students. Beyond the initial burst in the 1980s, there has been no widespread adoption of programming or coding as part of general education in either secondary or primary schools and no apparent impetus for such adoption, until recently.

Over the past five years or so interest in computer science and related topics in schools has resurfaced around the world. As described above, the terminology varies – programming, coding, computational thinking – but the same broad ideas are in play. The shift has not been sudden; there were hints of it in Friedman's (2006) discussion about what is needed in education for the flattened world. He argued that the increasingly interdisciplinary nature of problems and their solutions would require that workers in a variety of fields have at least some knowledge of coding but it is doubtful many have heeded that call. More significant drivers for renewed interest in coding have included corporations concerned about where they will find the talent to spearhead their next advances in computing and governments concerned about the future of their economies. It is those factors that are at work in Australia and driving the responses from governments recounted in the introduction.

The Digital Technologies subject in the new *Australian Curriculum: Technologies* (ACARA, 2015) has highlighted computational thinking as a key idea and presented some elements of programming and coding as core to a general education. The review of the national curriculum (Donnelly & Wiltshire, 2014) expressed scepticism about the proposals for digital technologies, apparently on the basis of suggesting that other countries are not doing it and Australia ought not lead the charge. Contrary to those claims by Donnelly and Wiltshire, there have been visible moves in the UK and elsewhere in recent years to embed coding and related material in school curricula (Balanskat & Engelhardt, 2015). The exchange in Federal parliament cited above suggests that our politicians recognise that it is an idea whose time has come but there continues to be public debate about the possible place of coding in schools.

There have been voices raised in support of an introduction to coding as part of a general education. Sterling (2015) is one who argues that the centrality of coding to modern technology makes it important for all to understand the possibilities even if we have no expectation that all students will have careers in coding any more than we expect that all will become artists as a result of studying The Arts in school. His position is actually less in favour of children using technology in classrooms than of their developing some understanding of the principles of computational thinking upon which the technologies depend. Indeed, he expressed outright opposition to compulsory laptop programs in schools, arguing that widespread access to mobile phones provides students with the necessary exposure to technology. Trying to rebottle the genie of (laptop) computers (or tablets and smartphones) in the classroom is probably a lost cause but understanding something of how things work and the potential for new applications is an important addition to being capable users of existing applications.

At the other end of the spectrum there are arguments that a little bit of coding in classrooms may be a dangerous thing (Merkel & McNamara, 2015). Their argument is that simplistic approaches to coding misrepresent the nature of information technology by encouraging ad hoc tinkering. The reality is that information technology depends upon the systematic approaches of software engineering implemented through team work. Their assessment of the proposed digital technologies subject is that the anticipated outcomes would challenge some students in university programs. The implication is that the curriculum is a futile venture because it demands too much of learners and teachers.

Interestingly, with the arguable exception of Kevin Donnelly, none of the voices cited above could claim much familiarity with school education, let alone the challenges of teaching computing to primary school children. Stuckey (2015) has voiced an opinion from an educational perspective in a blog post and admitted, in response to a comment, to having taught Logo in the mathematics curriculum when she was teaching in schools. She was not convinced that coding is the new literacy, preferring science for that role with coding included under its umbrella. She recalled that she learned to code in BASIC, a common activity in the early days of personal computing when there was little or no software other than what one could code, mostly by copying code sourced from magazines. She also noted that she no longer used that knowledge and knew few or no people who have any use for coding in their daily interactions with computers. She suggested that coding may be best learned outside of class time though the logic and computational thinking that underpin it may be more vital in general education. There are many things taught and learned in schools that have limited everyday utility for most people – trigonometry, calculus, atomic structure, geography of foreign lands, European history, to name a few. Nevertheless, we probably do not need to add to the list and should take care that new additions to the curriculum seem relevant. Certainly we want teachers to see the value of the curriculum even if it is not immediately apparent to the children in their classes.

The *Australian Curriculum: Technologies* (ACARA, 2015) specifies the creation of visual programs and refers to the use of a visual programming language. The most widely known language of that kind and the one most likely to be used in addressing those aspects of the curriculum is Scratch (scratch.mit.edu). Ironically Scratch has been developed out of the same laboratory that Papert established and led at MIT. It lends itself to the creation of animations and games that children will likely find motivating and the use of drag and drop pieces to construct simple programs makes it even easier to get started with Scratch than with Logo and guards against syntax errors although it remains possible to commit logic errors. The Scratch website supports an active community of users and provides for sharing of projects that can be copied and modified by other users or dissected in order to learn how particular effects were achieved. The website claims to have more than 12 million projects shared by users.

How far Scratch, or any of the similar languages that have appeared, can be pushed toward developing 'useful' programs is not entirely clear. Some variants are extensible and the RALfie project (ralfie.org) has developed some extensions to one variant, Snap! (snap.berkeley.edu), that enable remote control of Lego and other systems (Kist et al. 2016). It seems likely that most teachers, and learners, will find Scratch and its variants similar to Logo in what it can do and for that reason it is at risk of meeting a similar fate. The most obvious projects involve simple animations and games that may demonstrate knowledge of programming and other subject matter but have no obvious utility in the real world. Enthusiasts may persevere but the already crowded curriculum will squeeze out all but the most necessary and minimal efforts at coding in many classrooms.

Neither rapture nor rejection is a sane response

How should educators respond to this second coming of coding in the schools? Is this the long awaited rapture of computing in the classroom or will it end in another round of rejection? How should we be responding to this opportunity?

Neither unbridled rapture nor outright rejection would be a sane response to the second coming of coding for all. A sane response will be carefully considered and measured rather than driven by panic in the face of technological change.

A rapturous response would accept without question the claim that “coding is the new literacy” (DET, 2015b, p. 5) as though there is a single coding language that will serve all purposes when a more significant new literacy is the critical literacy to assess inflated claims. It would also signal acceptance that hopes for future employment rest upon ability to code when there are many people already working in industries built upon coding who do not code and no likelihood that will change. Coding is important but it is not the single magic bullet that will save our national economy and set us all upon the path to prosperity.

Rejection might be based on the optimistic view that we are producing, and will continue to produce, sufficient people with coding skills to ensure continued development in vital industries so there is no need for all to learn coding. Alternatively, it might be based on a pessimistic view that too few teachers are prepared to teach coding to all so there is no point in trying to do something that is likely to be difficult and probably has little value.

A sane response will fall between those extremes. It will recognise that society needs skilled coders but that there are other roles, even in the development of software, that require instead capabilities in visual design, process analysis or other fields that contribute to software development. It will also recognise that some understanding of coding, and more particularly of the computational thinking that underpins it, will be invaluable for all as a basis for understanding the risks and benefits of committing our lives to code in autonomous vehicles or elsewhere and for recognising problems that may, or may not, be susceptible to coded solutions. Coding as literacy in that sense of reading and responding to the world more effectively does have value for all.

Understanding the value of coding in everyday life is essential if we are to seriously promote coding for all as a core element of the school curriculum. Unless the relevance and value of young Australians learning something about coding is clear to teachers, parents, politicians, and the learners themselves it is unlikely to persist in the curriculum beyond the first flush of enthusiasm. What then is the value of coding for the average person?

The value of learning to code

I have some empathy with some of the views expressed by Stuckey (2015) who wrote "Many years ago I learned BASIC, which is a simple coding language. I never use it now but I still appreciate what learning it taught me about the logic and computational thinking that goes into programming." In the early 1970s I learned some coding through self-education on time share computing systems and taught some in mathematics classes in the later 1970s. I was an early programming hobbyist, buying my first Apple][computer in 1980, and progressed to writing programs to assist with various school administration tasks. Eventually I acquired a Graduate Diploma in Applied Computing and taught Information Processing and Technology in secondary schools before moving to the university. Like Stuckey (2015), I have some knowledge of programming and I do occasionally write code to complete work or personal tasks but most days I am not coding.

However, I am less confident about agreeing with Stuckey (2015) when she wrote "Coding really isn't an everyday practice in the way reading and maths are...it's probably more like understanding a car engine...if you basically understand how a car works you can drive and maintain it efficiently and effectively." The residue of my coding experience does have benefits in my application of computers in day-to-day life. A large part of that residue is probably the logic and computational thinking that Stuckey wrote about. Having some knowledge of programming helps me to see and follow the logic of unfamiliar applications. It also raises my expectations about all aspects of design in digital technologies and makes me more critical of applications and websites than some of my non-coding colleagues who have no reason to expect that systems should be more usable than they are. My capacity to analyse things in ways that lead me to construct spreadsheets or other tools to manage routine tasks is also enhanced and I am more likely than my colleagues to use tools like auto-text expansions and keyboard macros to automate repetitive tasks. On balance I think that having learned coding has developed my capacity for logical and computational thinking in ways that enhance my day-to-day use of digital technologies and that draw upon that knowledge of coding in meaningful ways.

For example, in recent days my teaching activity required me to assign content descriptions from the *Australian Curriculum: Technologies* to 180 students in my Semester 1 class and advise them of their assignments. I scraped the content descriptions from the ACARA website, pasted them in a text editor, and used search and replace to get them into a tab-delimited list that I could paste in Excel. I scraped student details from the participants list in Moodle and pasted that in another sheet in the same Excel file. There I wrote formulas to separate first and last names and then pasted content description codes against the names to register the assignment of content descriptions. I imported the student list into Filemaker Pro and then imported the list of codes and content descriptions and made the relational links. I was then able to create a simple script to send personalised email messages advising students of their assignments with codes and content descriptions. The limited coding required was facilitated by the Filemaker scripting system that is based on selecting from a list of available commands and setting relevant parameters, similar in some ways to a visual programming language in that there is no need to write code from scratch. Although there was no real coding required, thinking through the process and creating the necessary formulas and logic for the script drew upon my computational thinking skills developed through learning to program and code. Our institutional systems offer no means to achieve that outcome, other than by tedious manual processes, and I doubt that many of my colleagues could accomplish the same result. The power of computational thinking and some knowledge of coding is evident to me and I can see that even where somebody might not do work themselves understanding the potential offers power that is not otherwise available.

I could provide numerous other examples of where some knowledge of coding or computational thinking has enabled actions that would be impossible without such knowledge. Even where it is not possible for reason of secured access or limited skills to effect a solution directly, understanding the potential opens up possibilities for talking with those who have the necessary access and skills. Learning to code and to exercise related computational thinking can be beneficial even when the relevant skills are not applied directly. Such knowledge also provides the background from which to assess existing solutions and to make informed judgements about their suitability for particular purposes and the potential for improvement. That knowledge and related skills are sorely needed in a society where we otherwise have to accept whatever inadequate systems are foisted upon us. As was argued by Wing (2006), computational thinking is a "universally applicable attitude and skill set" (p. 33) that should be part of a current day education for all.

A way forward

The children now in schools are so-called 'digital natives' who, compared to older 'digital immigrants', are supposed to possess superior capabilities for working with digital technologies by virtue of having grown up with them (Prensky, 2001). That characterisation has been thoroughly discredited (Bennett, Maton, & Kervin, 2008); simple observation of younger people working with technologies should be sufficient to refute the idea of the 'digital native' as a generalisation. Many of them are adept with some common technologies and a few have extensive skills but for most of them confidence and facility with social media is a superficial veneer and there is little depth to their knowledge of the technologies they use. That is logical when we realise that the speed of technological development means that nobody is ever really a 'digital native' who grew up with current technologies. The pace of technological changes means that we are all perpetually 'digital immigrants' living by our wits with constantly evolving technologies.

The role of general education is not to prepare students to take up careers that may disappear before they enter the workforce but to develop the capability to live by their wits, manifesting resilience in the face of the only real constant, namely change. The native/immigrant dichotomy with respect to digital technologies has never really been valid (Bennett, Maton, & Kervin, 2008). The analogy of residents and visitors (Jones, 2011; White & Le Cornu, 2011) is probably more apt, better reflecting the differences between those who stay long enough in any context to develop some degree of comfort and those who do not stay long enough to care or really need to know. So far as coding or programming is concerned we need sufficient people with specialised skills to build the digital worlds that we will inhabit but not everybody needs to be a builder. For most of us it will be sufficient to understand the possibilities well enough to have a sensible conversation with the architect or builder or perhaps to have sufficient skill to be 'digital renovators' (Jones, 2011), able to adapt what we find to better suit our needs. Mere coding, the ability to express a given solution in a language that can be interpreted by a computer, will not be sufficient to achieve that. The underlying skills of computational thinking (Wing, 2006) will be much more useful as the basis for analysing problems and developing solutions that may ultimately require coding for their implementation. It is there that we need to focus and the current discourse about coding may be part of raising awareness of that broader goal.

If we interpret the *Australian Curriculum: Technologies* (ACARA, 2015) appropriately it is not about turning every child into a programmer or software engineer. It is about developing computational, design, and systems thinking as means toward creating preferred futures. For that to happen tools like Scratch can provide a useful starting point but we will need to move beyond that to engage students in designing and developing solutions to real problems that require computational thinking. Teachers who have limited experience of engaging in 'digital renovation' to adapt their own digital environments to be more suitable may struggle to imagine and implement suitably authentic learning activities (Lankshear, Snyder, & Green, 2000). Our real challenge may be in assisting teacher colleagues to develop the necessary attitudes and aptitudes to take charge of the digital technologies in their lives and prepare their students to do likewise. If we can do that we may not achieve rapture but may at least maintain sufficient enthusiasm for the second coming of coding to avoid rejection.

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Higher Order Thinking Through Calculus for Kids

Christopher K.H. Chin
Australian Maritime College, University of Tasmania, Launceston

Andrew E. Fluck, Jacky Chong
University of Tasmania, Launceston

Irene Penesis, Dev Ranmuthugala
Australian Maritime College, University of Tasmania, Launceston

Bianca Coleman
University of Tasmania, Launceston

The Calculus for Kids project has run over four years in five Australian states with 227 students in 18 schools. Participating students were 10-12 years old and studied integral calculus using computer algebra software (MAPLE). Their success in a post-test shows levels of achievement comparable to first year university engineering students. The project demonstrates how purposeful computer use can engender higher order thinking and provides exemplary evidence for systematic curriculum re-design in an era of ubiquitous information technology. The results in this report showed the learning outcomes were independent of student gender but responses to application questions were related to school rurality (based on ICSEA value). This makes the approach more attractive for general adoption and strengthens the argument for considering parallel developments in other topic areas.

Introduction

Roschelle et al. (2000) highlighted how supportive structural conditions within schools are essential for the effective use of computers to enhance student learning. As the authors suggest, the introduction of computers in schools alone does not improve student performance. Instead, computers must be seen as a learning tool to be used in combination with effective curriculum, pedagogy and assessment. These findings are consistent with those of meta-analyses conducted by Hattie (2008), and Tamim et al. (2011), both of which suggest computers are most effective when used in support of appropriate curriculum goals and teaching strategies. To provide the conditions necessary to support the effective use of computers, Roschelle et al. (2000) argue, schools must increase professional development opportunities for teachers, modernise their curriculum, and change their assessment practices from testing rote-learned concepts to tasks which require students to provide solutions to complex problems using higher-order thinking skills.

Since Kelman (1989) proposed the use of computers to support higher-order thinking, concerted research attention has investigated the effectiveness of computer technology for engaging students in curriculum-based tasks which promote higher order thinking. Roschelle et al. (2000), for example, examined the effectiveness of the SimCalc program, a technology-enhanced mathematics program, for improving students' higher-order thinking and learning of algebra. The SimCalc program involved the use of interactive computer software in middle school mathematics classes. Using the software, students could engage with and manipulate graphs and reflect on the resultant changes to the algebraic equations they represented. In addition to providing the software, the research team supplied curriculum materials, such as lesson plans, student workbooks and relevant computer files, and facilitated a range of professional development opportunities for teachers. The use of the computer software, therefore, was supported by relevant mathematics curriculum and pedagogy. Across three large-scale studies of the learning gains experienced by Year 7 (1st year n = 1,444, 2nd year n = 997) and Year 8 students (n = 657), the researchers found the SimCalc program significantly increased students' learning in algebra (effect sizes of 0.63, 0.50 and 0.56, respectively) (SRI International, 2011).

While these results provide positive support for the use of SimCalc for improving students' algebra learning, it is important to note that a range of other variables were also shown to have an effect on student learning, albeit an inconsistent effect between the studies. In the second study, for example, the use of SimCalc was a negative predictor of student learning gains in schools with socio-economically disadvantaged students. Ethnicity was also found to have a relationship to student learning gains in the second study with Hispanic students demonstrating smaller learning gains than Caucasian students. Furthermore, students with greater prior knowledge of algebra tended to complete more of the exercises in their workbooks and with greater accuracy than peers with less prior knowledge. The researchers subsequently found workbook completion (using the software) and accuracy to be an important predictor of student learning gains (SRI International, 2011). These findings continue to highlight how the effectiveness of computer technologies for learning can be mediated by range of other, often structural, factors.

More recent research examining the use of SimCalc has further demonstrated the effectiveness of the program for improving students' algebra learning. Hegedus, Dalton & Tapper (2015) evaluated the use of SimCalc in high school classes (15-17 year old students). 606 students participated in the first year evaluation of SimCalc while a further 293 students participated in the second year replication study. In each year of the study, the researchers found students who used SimCalc recorded higher relative gains in post-test scores than students who did not use the software. In Year 1, SimCalc students recorded relative gains of 25% (standard deviation = 0.49) compared to students in the control group (11%, standard deviation = 0.47). The replication study (Year 2) recorded similar gains: 26% gains for SimCalc students (standard deviation = 0.50) and 14% gains for control students (standard deviation = 0.47). These findings support the conclusion that SimCalc is effective in increasing students' learning.

This paper further describes the ***Calculus for Kids*** project (Chin, Fluck, Ranmuthugala & Penesis, 2011; Fluck, Ranmuthugala, Chin & Penesis, 2012) where computer software is used to teach primary school students integral calculus, normally taught in Year 12. This research provides us with information on how these students cope with real-world application problems and their ability to apply to other problems. The Calculus for Kids project differed from research using SimCalc by expecting students to use computers during the post-test.

Literature

The notion of a 'technological gender gap' between male and female computer-related behaviours and performance, attitudes towards computers and self-efficacy for completing ICT tasks has received considerable research attention over the past twenty years (Broos, 2005; Colley & Comber, 2003; Zhong, 2011). Whitley's (1997) meta-analysis reviewed 82 American and Canadian studies which claimed to have found gender differences in computer-related behaviours and attitudes in adult, college, high school, middle school and elementary school student populations. Although effect sizes varied within these individual studies, Whitley's analysis determined the largest effect sizes were generally found for high school students and attributed this, in part, to a "socialisation process" which historically portrayed computer use as the domain of boys and men. Whitley's analysis also revealed, although gender differences were found to be statistically significant, the effect size was small ($d = 0.326$), suggesting the result may even be representative of sampling errors or self-selection biases within the reviewed studies.

More recent research has examined gender differences in computer behaviours, attitudes and self-efficacy using national and international student performance data. Tømte & Hatlevik (2011) utilised data from the 2006 Programme for International Student Assessment (PISA) Information and Communication Technology survey to describe the relationship between computer self-efficacy and gender in 15-year-old Norwegian and Finnish students ($n = 9{,}400$). The survey asked students to self-report on their ability to complete a series of 14 different ICT tasks. While the authors did find some evidence of gender differences related to ICT self-efficacy it is significant to note both male and female Norwegian students reported higher levels of ICT self-efficacy than all Finnish students. At the national level, Finnish males reported higher levels of ICT self-efficacy than Finnish females, while Norwegian females reported higher levels than Norwegian males. The conflicting nature of these results and the localised context from which the data for this study was drawn means further research is warranted to ensure the findings can be generalised to a wider population.

In Australia, findings derived from the 2014 National Assessment Program (NAP) ICT literacy assessment provide evidence of gender differences in ICT literacy test scores. The assessment tested the ICT literacy of 11,000 Australian students in Year 6 and Year 10. In the test, girls out-performed boys in both year levels (on average girls' scores were 23 points higher than boys in Year 6 and 29 points higher in Year 10) (Australian Curriculum, Assessment and Reporting Authority, 2015). These results stand in contrast to older research claiming boys are more skilled in ICT (Attewell & Battle, 1999; Imhof, Vollmeyer, & Beierlein, 2007; Zhong, 2011). The NAP results are more consistent with very recent findings from Belgium (Aesaert & Van Braak, 2015) and the United States (Hohlfeld, Ritzhaupt, & Barron, 2013) which also found girls out-performed boys on ICT skills tests.

Our enquiry was to see if using computers made it possible for such young students to understand integral calculus and apply their understanding to solve mathematical and real world problems. In addition, we were interested in the ways the genders approached learning in this computer-intensive environment, and whether they differed in their achievements.

Methodology

The project primarily focuses on teaching integral calculus to Year 6 primary school students (aged 10 to 12 years) recruited in Australian schools in Tasmania, Victoria, South Australia, New South Wales and Queensland. Research ethics for this study was first sought and approved by the individual states. An expression of interest was then sent to schools to recruit the teachers. Once the schools confirmed their commitment, a teacher from each of these schools were flown to Launceston and trained in a one-day workshop. The computer software used is MAPLE® as in the first and second year Mathematics units in the Bachelor of Engineering (Maritime) programs at the University of Tasmania. This software was chosen for its simplicity, WYSIWYG and user- friendly configuration. Most importantly, it retains classical mathematical notation, unlike most other computer algebra software. During the workshop, the teachers are trained to deliver a total of 13 lessons. For each lesson, the teachers are provided with an interactive PowerPoint presentation, a Maple worksheet datafile and a PDF worksheet document containing basic questions and real world application problems. Teachers are also provided with an answer booklet illustrating the worksheet responses students should obtain for all 13 lessons. The teachers return to their schools to implement the lessons with students.

Unlike many other educational investigations, a pre-test of ability was not conducted. There were two reasons for this. Firstly, this is a fairly short intervention study, and one of the lessons was expected to be used for a post- test of learning achievement and attitudes to learning mathematics. That amounts to nearly 8% of the learning time. Doubling the test time to 15% (or adding another lesson) would need to be well justified. The second reason for omitting a pre-test, was the topic. It was generally agreed that none of the students could be expected to have been taught or to know anything about integral calculus. The very small chance that one or two would register a score on a pre-test of the topic did not seem sufficiently likely to justify the demoralising effect on all the other students. Therefore the pre-test was designed out of the learning sequence because it had little value and could demoralise students.

The students are first taught the basics of how to "drive" the software in order to perform simple calculations. Then an introduction is given on plotting points, lines and defining a function. In order for students to appreciate integral calculus and to address past comments from reviewers, two lessons were added to the program. These lessons focus on the formation of equations found within the program. To help students understand where the equations come from, we start with a basic parabola y = x2 and then extend this to the general equation of a parabola y = a(x h)2 + b . This is accompanied with graphical explanations. See Figure 1 for an example.

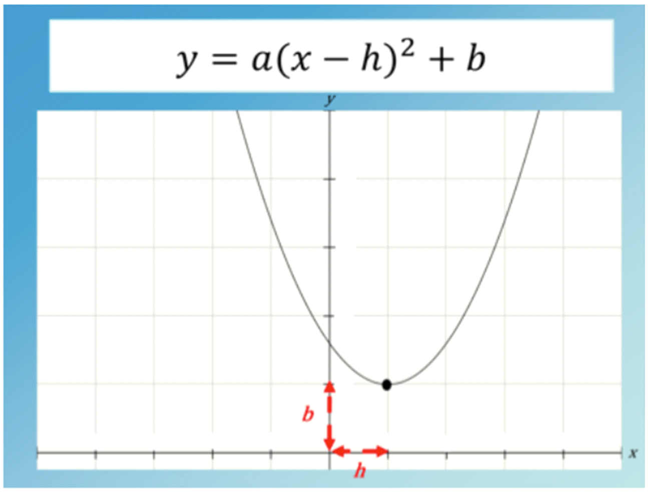

Figure 1: Graphical representation for the general equation of a parabola

The following lesson required students to formulate the equation of the parabola based on the given parameters. An application problem is given in Figure 2 where students are required to determine the equation that models the cables of the Golden Gate Bridge. This part of the program equips students to derive (in some limited circumstances) the function equation that describes a particular curve. Thus it more closely parallels conventional courses in integral calculus, and provides a better demonstration of higher order thinking which corresponds to 'creating/origination' in Bloom's taxonomy (1956). In solving this problem, students have to super-impose a Cartesian grid onto the diagram, then work out the coordinates for the turning and one other point. They substitute these values into the general equation for a parabola, leaving one unknown variable to be found. This is calculated by using the 'SOLVE' function in MAPLE, and so the precise equation for this practical example can be found.

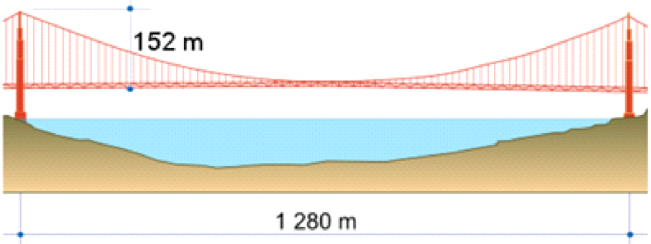

Figure 2: Example of an application problem

Once these preliminaries are delivered, students are introduced to the concept of integration and shown where integral calculus can be applied. An integral application question is shown in Figure 3 where students are asked to determine the equation of the parabola and the amount of fabric needed for the end section to make the tent. In the preceding weeks leading up to the topic on integral application questions, students have already learned that to find the area under a curve, they need to perform integration. They were taught what the limits (lower and upper limits) of integration are. Combining this knowledge and the previous knowledge learnt in setting up the equation of a parabola, they are then able to find the area underneath the curve and hence determine the amount of fabric required.

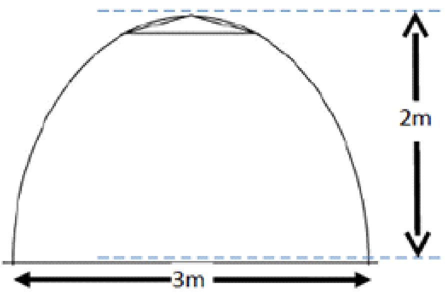

Figure 3: Example of an integral application problem

Further sample application questions can be found in articles published by the co-authors (Fluck, Chin, Ranmuthugala & Penesis, 2014; Chin, Fluck, Ranmuthugala & Penesis, 2011; Fluck, Ranmuthugala, Chin & Penesis, 2012; Penesis, Chin, Ranmuthugala & Fluck, 2011) amongst others.

Members of the research team visited each school about half way through the program to observe the class, ensure the program was on track, assist with any computer difficulties and obtain feedback from the teacher and students. These visits are vital for the continual refinement of the resources where needed. The research team also monitored progress via telephone conferences and emails with the teachers to ensure smooth progression of the program. Figure 4 shows a sign located on the oval of the school. This attracted attention and interests from parents, the public and other neighbouring schools.

In the final stage of the program, all students are required to take a test to assess their knowledge and skills that they have gained throughout the programme. The test is based on questions drawn from first year maritime engineering mathematics examination papers. The test consists of 15 assessed questions, of which there are 7 application questions. Immediately after the test, an attitudinal test was also administered. This included a Mathematics self-efficacy scale (Tapia & Marsh, 2004) and a Mathematics and Technology Attitudes Scale (Barkatsas, 2004; Pierce, Stacey & Barkatsas, 2007).

The completed MAPLE files and surveys were collected and sent back to the research team for analysis. By return, schools and students receive a short descriptive certificate showing their learning achievement and attitude to learning mathematics relative to the means for the class.

Figure 4: School sign

Results and Discussions

One of the main aims of this research is to determine whether the students are able to transfer higher level concepts and skills and apply them to real world application problems using appropriate technology. To date, a total of 227 students in 18 schools have participated in the Calculus for Kids project. This project spanned five Australian states which included Tasmania (pilot project), Victoria, New South Wales, Queensland and South Australia.

Table 1: Student demographics

State	Location	ICSEA	Total Scores			Scores – Females			Scores – Males			Application Questions		
			n	M	σ	*n*	μ	σ	*n*	μ	σ	*n*	μ	σ
NSW	Rural	911	18	70.3	16.6	9	75.9	15.4	9	64.7	16.7	18	59.72	18.81
QLD	Urban	1027	90	66.1	17.1	42	66.9	16.0	48	65.4	18.1	90	51.31	20.67
SA	Rural	945	21	51.0	19.2	6	43.9	18.6	15	53.9	19.3	21	28.23	22.64
	Urban	1001	22	63.4	19.1	9	69.9	8.8	13	58.9	23.1	22	49.03	15.52
VIC	Urban	1092	76	75.9	13.3	35	78.1	10.6	41	74.1	15.2	76	62.59	17.41

Table 1 provides a summary of the student demographics, location, Index of Community Socio-Educational Advantage (ICSEA), mean test scores based on gender and performance in application questions for the schools (excluding Tasmania) involved in the project. Note that the mean ICSEA value is 1000 with a standard deviation of 100 and that values below the mean indicate schools with fewer advantages. Here, ***n*** is the sample size, μ is the mean and **σ** is the standard deviation. All data was pooled and analysed using SPSS Version 21 (IBM Corp., 2012). The mean total scores **M** for the whole test, as shown in column 5 of Table 1, are all above the university pass grade of 50%.

Table 2 shows the result of an independent-sample t-test which was conducted to compare the test scores for students from rural and urban areas. The results showed that there was significant difference in scores for rural students (M=42.77, SD=26.10) and urban students (M=55.60, SD=19.64; t(47)=2.91, p=0.006, two tailed). The results show that the schools' location has a significant difference when comparing the mean scores, because the t value is above the critical value. This could be due to urban schools are better staffed, have better facilities and study environment, and students subjected to positive study habits.

Table 2: Result of t-test analysis of the influence of school location on performance of application questions

Location	*n*	μ	σ	*t*-value	degrees of freedom
Rural	39	42.77	26.10	2.91*	47
Urban	188	55.60	19.64		

*Significant at 0.05 level

On whether gender plays a part in the performance, an independent-sample t-test was conducted to compare the test scores for male and female students. As shown in Table 3, there was no significant difference in scores for male students (M=51.72, SD=21.86) and female students (M=55.49, SD=20.69; t(225)=1.32, p=0.19, two- tailed). This result corroborates research done by Hyde and Mertz (2009) and demonstrates female students are as accomplishing as males, possibly due to the various multi-media techniques used in the presentation and delivery of the teaching materials.

Table 3: Result of t-test analysis of the influence of gender on performance of application questions

Gender	*n*	μ	σ	*t*-value	degrees of freedom
Females	101	55.49	20.69	1.32*	225
Males	126	51.72	21.86		

*Significant at 0.05 level

The last question on the test asked students "What is Calculus good for?". Some of the comments gave us a better idea of what students think calculus can be applied to:

integral calculus is useful because we can find area under a curved line and can also find the area of bridges, skate ramps etc by using a method y=a(x-h)^2+b.*

because you can work out the area of the thing you might need to carpet or paint and more everyday things.

because it gives us a clue on time velocity and speed which is related to real life.

For jobs such as engineering, construction or building any object of any kind.

Because if you want to become an engineer you will not do simple shapes like triangles and squares you will be doing complicated shapes and those shapes are in calculus. So if we learn calculus young then we will have less difficulty when we are older and we are doing calculus. So calculus helps us learn the real world and shapes that we will actually use if we become engineers or architects so that's why it is useful.

It was quite apparent these primary school students had acquired a substantial understanding of the mathematical techniques of integral calculus, and more importantly, their potential applications. They were ready to make the leap into learning at a higher level. But are schools, teachers and curriculum designers ready to incorporate computers into learning programs to this degree?

Conclusion

The results from this Calculus for Kids project has shown us that using computers can transform how students learn mathematics. The results indicate students are able to understand the concepts and apply them to the relevant application problems from analogical reasoning rather than plain memorisation. This is supported by research done by Richland and Simms (2015). Of particular importance is that by using the MAPLE software and multi-media teaching materials to assist visualisation, students were able to master concepts at a far younger age than considered appropriate for this subject matter. It is tempting to speculate what other academic areas could be similarly developed to allow a leap forward with curricula. As cited in the introduction, computers can make a big difference in school education if they are used in the context of "appropriate curriculum goals and teaching strategies". Following current trends for ubiquitous computer use in classrooms, gender-neutral demonstrations of higher order thinking such as Calculus for Kids are an important beacon into the future.

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Cultivating Creativity

Boost learning by igniting students' imaginations

Gail Marshall

Gail Marshall is a writer and editor for The Fresno Bee, a major metropolitan newspaper in California. She also owns and operates a freelance business, Marshall Arts Communications Consultants.

When Sylvia Libow Martinez was a little girl, she didn't think of herself as creative. That would be her artistic friends who could make dragons and princesses come to life on a page with their paintbrushes, felt-tip pens and charcoal pencils.

"My mind didn't connect with my hands that way," she says.

It wasn't until her mind and hands connected with the tools of technology that she could not only make images pop off a screen, but she could make things – things that solved problems.

"Computers allowed me to be creative in a way not possible without these technology tools," says Martinez, now a programmer and engineer. "It also allowed me to see that creativity isn't just about the hand, it's about the mind and allowing yourself to be mindful of the world and the creative potential in every endeavor."

Today, Martinez teaches others to discover their own creativity through technology. She is the co-author of *Invent to Learn: Making, Tinkering and Engineering in the Classroom*. You'll also find her acting as a mentor and adviser to the Stanford FabLearn Fellows, a group of 18 educators working at the forefront of the maker movement in all corners of the globe. They teach in FabLabs, makerspaces, classrooms, libraries, community centers and museums – all with the goal of making learning more meaningful in the modern world.

Her book and workshops are designed to challenge teachers to venture out of their comfort zones and become learners side by side with students in this brave new world.

Everyone has a stake

She is not alone. There is a constant chatter in education about the benefits of creativity and how to teach it. Can it be taught? What does it look like in the classroom? Why is it important? What can children teach adults about creativity? What are the leaders doing right now to push this idea forward? Are our test-heavy classrooms creativity killers? How do we get more girls involved? Everyone from business executives to students has a stake in this vital, yet often viewed as loosey-goosey, concept.

Martinez sees two clear connections between the maker movement and creativity in the classroom.

"One is to make mathematics relevant to the creative process," she says. "Robotics, sensors, CAD-designed 3D fabrications and new programming environments add measurement, precision, analytics, prediction and mathematical accuracy to many kinds of projects.

"The second is design. Design is the engine that powers the ability to 'play' with powerful ideas and immediately bring them to life. Tools – both software and hardware – create the potential for a rich iterative design cycle where real things are made better by the ability to improve them, not just do over."

Martinez says the heart of her message in Invent to Learn is to place the child at the center of the learning experience.

"To create," she says, "is to bring something from inside yourself to the outside. This is what happens when children make things in a supportive learning community. They make their ideas real, and as this process unfolds, teachers who are watching carefully can examine the creative process for signs of learning.

"The main job of a teacher is not marking or talking. It is being an anthropologist on a continual expedition to reveal how children approach their work."

Just don't mistake the words "child-centered" as meaning "no teacher needed."

"The art of teaching," she explains, "involves watching what a child does and says when a challenge arises, adding strategic comments without telling a child what to do, and shaping the learning environment toward invention and powerful ideas. Making things that come from your own imagination is a rich process that makes learning visible in a completely different way than tests. When a teacher sees that 'teachable moment,' it's because it's a live interaction between teacher and student. Teaching in this way becomes a creative endeavor, and is more satisfying to teachers."

If we don't know, we'll find out

If you want to take a peek inside a classroom to see how all this looks in real life, Martinez suggests visiting Tracy Rudzitkis of New York City. A computer teacher in a public middle school, Rudzitkis managed with very little fanfare or finances to create a makerspace in her school where children are welcome to drop in during lunch time. She often hosts up to 70 children at a time.

In one lunch period, Martinez saw children programming in several different computer languages, making stop-motion videos, creating animations, programming computer games, working with robotics, and building machines with electronics, motors and much more. The program has moved from being extracurricular to becoming a new science class Rudzitkis is offering during the school day. "I admire her optimism, enthusiasm and ability to do what needs to be done in spite of people saying it can't be done," Martinez says.

Rudzitkis has attended Martinez's summer institute for educators, Constructing Modern Knowledge, for seven years and this year will be a senior fellow.

It's no small detail that Rudzitkis is a woman in a field dominated by men. Martinez's next book is a passionate pursuit of that issue. It is all about girls and STEM – not just how to inspire the next generation of women scientists and engineers, but also how to make STEM subjects real and relevant to inspire all students.

"There are a lot of depressing statistics about how girls from kindergarten through careers are underestimated and devalued in these fields. I'm in the research phase now, and I'm already starting to collect a lot of stories about what's going right, not just what's wrong."

Martinez's discovery is showing tangible ways to help girls develop their creativity in their classes.

"Girls as a group tend to have some strengths that really support authentic learning," she says.

"One way is that they tend to have better 'soft' skills like collaboration and coming to consensus. Research also says that they value experiences that are grounded in real life and helping other people."

It's easy to see that the real-world technology and the open-source, collaborative nature of the maker movement play into these strengths. However, too many classrooms are closed systems where sterile textbook exercises are the only problems and competition stifles creativity.

"Schools tend to favor and reward only one kind of problem-solving. Linear, analytical approaches are seen as 'academic' and 'rigorous' while things like talking to others, thinking out loud, tinkering and trying lots of different approaches are seen as emblematic of a confused, naïve approach to learning.

"This is the way creative people work, and honestly, most scientists and engineers. No real job is done in a vacuum where you never talk to others and never make a mistake. We do so many children, not just girls, a disservice by discounting their natural problem-solving styles. It discourages and disempowers them, convincing learners that their ideas and passions are not wanted. If we want to solve the problems that face us in the future, we have to expand what we mean by being 'good' at STEM and [understand] that creativity is the key to every subject," Martinez notes.

Delivering inspiring curriculum

Creative catalyst, performance coach and inspiration impresario.

That's the job description for Kevin Carroll in his own consulting firm, and what better way to describe a man who started the rubber bracelet craze, whose inspirational quote appeared on 17 million Starbucks grande cups and who has worked with the National Hockey League, ESPN, Nike, the National Basketball Association, Walt Disney Company, Mattel, Hasbro, Procter & Gamble, Discovery Channel and Capital One, just to start. He was also a keynote speaker at ISTE 2014 in Atlanta.

Carroll is the author of several books, including Rules of the Red Rubber Ball, What's Your Red Rubber Ball?!,and The Red Rubber Ball at Work. So, what is with the bouncy thing?

"A red rubber ball saved my life," says Carroll, who now travels the world telling his story. In Facebook language, "it's complicated" describes his upbringing. As a child, his troubled parents abandoned him and his two brothers in a trailer for nearly a week with little food or water. His grandparents stepped up to raise the boys, and they did their best trying to guide them through life in a very rough urban neighborhood.

There was one saving grace on those mean streets: a playground. And it was there that he discovered the simple thing that saved his life, a red rubber ball used in four-square, kickball and many other childhood games. Eventually, that red rubber ball led him to make friends, pursue healthy sports and eventually assemble a dazzling résumé that includes meetings with heads of state.

"I believe that the 'red rubber ball' is an activity that inspires us, brings us joy and sparks our imagination to dream big!" he says. "Discovering one's 'red rubber ball' empowers a student to make a commitment to chase and pursue it daily.

"Imagine if a teacher would ask a student: What brings you joy? What inspires you? What do you find irresistible and tickles your brain? The 'red rubber ball" questions and the answers provided by a student would assist a teacher/educator with valuable insights to craft and deliver curriculum that inspires students. Imagine school buildings and classrooms filled with students who arrive each day excited to actively participate in their learning experience."

Carroll is known for being a passionate advocate for encouraging curiosity and play in schools. Is there a connection between those things and creativity?

"Absolutely!" is his emphatic answer. And it's not just his idea.

Here are three insights and reminders that he enjoys sharing about the role and value of curiosity and play as catalysts for a student's creativity:

- "Play isn't the enemy of learning... it's learning's partner." – Dr. Stuart Brown, a pioneer on research on play
- "Fresh air, nature and regular physical activity breaks are considered engines of learning."– Finnish education philosophy
- "I have no special talents. I am only passionately curious." – Albert Einstein

Can creativity be learned?

Scott McLeod, Ph.D., of Ames, Iowa, knows exactly what it's like to have a creative child at home.

He is the director of learning, teaching and innovation for Prairie Lakes Area Education Agency and an ISTE member. In August, he will take a position as an associate professor of educational leadership at the University of Colorado in Denver.

But at home, he and his wife, Betsy, are the parents of three bright children. His son, Colin, 12, turned his family's ping-pong table into his own little maker factory.

In a blog a few years ago, McLeod wrote in detail about what life is like with the constant creativity of a maker at home. Every box becomes a dozen kinds of inventions. At the end, he challenges teachers: "Are you ready for him?"

Now, a few years later, he says, "There are individual teachers that are ready for my maker son. They find ways to accommodate his interests in creative writing, board-game making, and social media and digital video creation as part of his classroom assignments. And there are other teachers who have failed to tap into his potential."

So, can creativity be learned?

"I think we are born creative," he says. "The challenge is to keep schools from squelching our natural creativity. Classrooms can be powerful socializing mechanisms that turn active, inquisitive, curious creators into passive, disengaged, 'just tell me what to do' rule followers."

Finding success stories

McLeod travels internationally in his work and has seen many schools that impress him. Two stand out when it comes to empowering students: the Discovery and Unlimited schools in Christchurch, New Zealand, and the American School of Bombay in Mumbai, India. These learning environments typically focus on deeper thinking, greater student agency, authentic (and often community-embedded) work and rich technology infusion.

What does that look like in a typical classroom? McLeod points to The Hewlett Foundation website, which describes deeper learning at King Middle School in Portland, Maine.

"Imagine that you walk into an eighth grade classroom. A small group of students is cheering. They've just discovered that the wind turbine they designed and built can produce almost six volts of electricity. One of the students tells you that she had to redesign the blades several times, but she persevered. Why? She was inspired by a book she read in English class, *The Man Who Harvested the Wind*, about a man in Malawi who built a wind turbine out of scrap metal to bring electricity to his village.

"Another student shows you a map she made in social studies class. She points to the areas where wind turbines could be built in her state. And she proudly presents her persuasive essay, which explains the value of wind turbines.

"These students are engaged in deeper learning,which means they are using their knowledge and skills in a way that prepares them for real life."

Creativity in real life

What does creativity in "real life" look like through the eyes of students? Meet Miles Rasmussen, 16, a sophomore at Churchill High School in Eugene, Oregon. He already sees a future for himself as a nature or wildlife photographer.

He just got back from a two-week family trip to Belize and is still exhilarated. He took along his drone and GoPro and Nikon cameras.

"I took tons of pictures and videos of snorkeling, Mayan ruins, the jungle, different towns and lots of wildlife," he says. "I cannot wait to finish the editing!"

You can be certain that his requisite recounting of "what I did on my spring vacation" essays will go far beyond the norm for the average sophomore.

Miles didn't wake up one morning shooting drone footage off exotic islands. His creative expression through photography began about age 6, when he asked for a camera. At that time, his world was his family's backyard.

He has learned much of what he knows the old-fashioned way: trial and error. "I've gotten really good at finding online resources such as instructional videos on YouTube and online forums."

As he grew older, he took classes at school in digital photography, which taught him to use the digital camera and digital media. His world is much broader than the backyard now, and he has used his family's vacations to the ocean and mountains as the settings for his photos and films. He has extended his world beyond the bounds of his own eyes and footsteps.

Support beyond the classroom

Miles' parents, Anne Williams and Matt Rasmussen, are not techies, so Miles has led the way to much of his own progress. As the price and sophistication of his equipment grew larger, they made sure he had "skin in the game" by requiring him to earn at least part of the money.

They have supported his creativity, though some new technology – like the drone – gave them pause. It was especially concerning when the Federal Aviation Administration (FAA) got involved and the media reported stories of people misusing the device and causing interference with other aircraft.

But Miles did his research online. "Just a few weeks before I planned to buy my drone," he said, "a new law took effect that required all drones to be registered with the FAA. At first, I was worried, but it was easy to figure out how to do it. I got the drone registered as soon as I got it. I haven't had any problems, including when we had to take it through customs in Belize."

Miles compliments his parents on their support of his curiosity and creativity. Their willingness to explore the outdoors with him, allowing him to explore the natural world they love, just poured fuel on his creative fire. His first videos were daily diaries of their vacations, including a trip to their cabin in Rosswood, British Columbia, and a one-night winter camp in the Oregon Cascades.

"I haven't always followed this myself, but be open-minded to your kid's ideas, even when they push you out of your comfort zone," Anne Williams advises. "Take the time to really listen, observe and explore with them. You'll be encouraging them, and chances are you'll find yourself genuinely interested in what they are up to."

Technology can make every classroom creative

Veteran educator and ISTE member Mark Gura of Jupiter, Florida, says "through technology, every classroom can be a creative classroom." Students and teachers can say much more now that there are these wonderful tools to help them say it. It's the democratization of the media, he says – in other words, it's for everyone.

Gura grew up in New York City, where he taught for more than three decades. A prolific writer, he recently completed his fifth ISTE book, Make, Learn, Succeed: Building a Culture of Creativity in Your School. He also teaches graduate teaching courses online, and as a former teacher of visual arts (among many other subjects) and as a technology director, he says he has been involved in promoting creativity his entire life.

He is convinced that the best place to inspire teachers to be creative is right at the beginning, in our teacher education programs. Classroom teachers need to make developing student creativity a goal.

Light a fire

In his own teaching, he sees the power of firsthand joy.

"The great thing about this is that once a student has had a few experiences like this, the experience of education itself is transformed, as the old saying goes, 'Education is not the filling of a bucket but the lighting of a fire!' What I want people to know about student creativity is that engaging students in activities to develop their creativity is one predictable way to light that fire.

"I've spent a lifetime in pursuit of that, and I think that in the end, it is probably the very most important thing we educators can do for our students. By using student creativity as a focus, we have a very clear path to take toward that goal!"

What if teachers had the tools to understand and enhance the creative thinking of students?

Professor Romina Jamieson-Proctor
Australian Catholic University

Professor Peter Albion
University of Southern Queensland

The economic and social well-being of Australia is based on its citizens' ability to adapt and create knowledge and products in response to societal needs. The fruits of creativity enrich our culture and improve the quality of our lives, both individually and collectively. This paper presents a rationale for a theoretical framework for Distributed Creativity in classrooms that might be used to explore and define forms of complementarity among students to support production of creative ideas or products; and investigate ways in which Distributed Creativity can be used by researchers and educators to study and optimise student creative potential. The Distributed Creativity framework is predicated on the transformational potential of digital technologies to afford students the capacity to work collaboratively and engage in what has been termed mini-c creativity.

Background

The economic and social well-being of Australia is based on its citizens' ability to adapt and create knowledge and products in response to societal needs. Schools should play a major role in ensuring students acquire the necessary social, cognitive and affective skills to be Australia's creative problem-solvers in the Asian Century (Commonwealth of Australia, 2012). As argued by Chubb (2015) we should focus less on 'future-proofing' and more on 'future-priming' to prepare young people to respond creatively to future challenges and opportunities. Pink (2005) notes that creative thinking is increasingly necessary to accomplish goals in our complex, interconnected world and suggests that a new paradigm for schools is needed to allow students to experience the richness of creative thinking and learning which is not afforded them in the current education climate of high- stakes testing and scripted curricula. Pink states

> today, the defining skills of the previous era - the 'left brain' capabilities that powered the Information Age are necessary but no longer sufficient. And the capabilities we once disdained or thought frivolous – the 'right brain' qualities of inventiveness, empathy, joyfulness and meaning - increasingly will determine who flourishes and who flounders (p. 3).

Mishra, Koehler and Henriksen (2011) argue for transformative learning, focused on "trans-disciplinary thinking" (cognitive skills that cross disciplines) and new technologies, to create contexts where creative thinking thrives. The Australian Curriculum recognises the importance of facilitating cross-disciplinary capabilities by including suggestions for links between specific learning areas, Cross-curriculum Priorities and seven General Capabilities underpinning all learning areas: Literacy; Numeracy; Information and Communication Technology capability; critical and creative thinking; personal and social capability; ethical behaviour; and intercultural understanding. The General Capabilities encompass the knowledge, skills, behaviours and dispositions that, together with curriculum content in each learning area and the cross-curriculum priorities, will assist students to live and work successfully in the twenty-first century. They play a significant role in realising the goals set out in the Melbourne Declaration on Educational Goals for Young Australians (MCEETYA 2008) that all young people in Australia should be supported to become successful learners, confident and creative individuals, and active and informed citizens" (Australian Curriculum Assessment and Reporting Authority, 2011).

Creative thinking has received recent attention from both educators and psychologists and there is a consensus that the development of creative thinking by students is critical for long-term sustainability (Runco, 2007).

However, even though creativity has been seen to be increasingly significant in education in the latter part of the 20th century and the first decade of the 21st century (Craft, 2008), and despite the consensus view that each of us possesses creative potential, and that the benefits of fulfilling creative potentials accrue to both individuals and society (Runco, 2007), "researchers, psychologists, educators and policy makers still talk about creativity in very generic and fuzzy terms" (Mishra, Henriksen, & MSU Deep Play Research Group, 2012, p. 20).

None the less, internationally considerable work has been done since the turn of the century to provide guidance for educators with respect to creativity in classrooms. For example, the National Advisory Committee on Creative and Cultural Education (NACCCE, 1999) in the UK, convened by Sir Ken Robinson, synthesised empirical research evidence and concluded that 'creative learning' involves children experiencing innovation in the classroom, control over activities and their evolution, together with a sense of relevance and ownership of their learning, and that these four features are also characteristics of creative teaching (Jeffrey & Woods, 2003). Further, NACCCE recognised the need for guidance on creative teaching and learning which resulted in the Qualifications and Curriculum Authority undertaking a number of years of work to innovate curriculum, learning and pedagogy in the UK, informed by the definition of creativity presented in the NACCCE Report, and the cultural framing of creativity as a democratic concept. NACCCE saw creativity as "imaginative activity, fashioned so as to produce outcomes that are original and of value" (NACCCE, 1999, p. 29). Their democratic approach to creativity, and the linking of creativity to culture, viewed creative learning as empowerment in and beyond the classroom, which was a significant shift away from the prevailing view of creativity as only accessible to the gifted (Jeffrey & Craft, 2004; Sefton-Green, 2008).

In recent years, there are several distinguishable discourses observable in the research literature with respect to creative learning. Banaji, Burn and Buckingham (2006) have succinctly synthesised nine of these: the creative genius rhetoric that emphasizes extraordinary creativity in a range of domains; the democratic and political rhetoric where creativity offers empowerment; the notion of creativity as ubiquitous in which creativity is pervasive; creativity as social good where it is essential to a 'good life'; the rhetoric which emphasizes the economic imperative of creativity for individuals and countries; the approaches that emphasize play which is viewed as the foundation of adult creativity; the approaches focussing specifically on creativity as a form of cognition; the discourse around creativity and new technologies that emphasize the affordances of new technologies for creativity; and lastly the creative classroom discourse that draws connections between individual and collective creativity in classrooms.

However, the global drive for accountability and to raise standards creates an unmistakeable tension with the current thinking in terms of creative learning, where there is a commitment to nurturing ingenuity, flexibility, and generative capability (Craft, 2008). In reality there are significant challenges for educators seeking to frame and develop creativity in schools, arising from almost irreconcilable underpinning discourses that determine how creativity is envisioned and enacted in classrooms (Craft, 2008).

Numerous questions are generated by the research literature on creativity including: How is it that some people are considered creative while others are not? Is creativity simply a cluster of cognitive skills (Guilford, 1950) or is it more than that? Is creativity domain-specific or domain-general? Is it dependent upon social and environmental conditions? How might information and communication technologies (ICT) assist children to develop and demonstrate creative thinking? All of these questions are worthy of study and have received periodic attention in one form or another in the past five decades by psychologists, sociologists and educational researchers.

Although the 'fuzziness' about the construct of creativity may be due to its complexity or the lack of a consistent definition (Sternberg, 1999), it has been argued that a more pressing problem for educators is the creation of a workable framework which can be used to help students develop their creative thinking potential (Mishra et al., 2012). Further, many researchers have noted that schools are generally structured to maintain rigid discipline boundaries (Robinson, 2003) but this is contrary to how extraordinary thinkers operate (Root-Bernstein & Root- Bernstein, 2004) as "most creative people do not view their work as confined to their discipline, but rather are inspired and elevated by connections within and between other disciplines" (Mishra et al., 2012, p. 19). The Australian Curriculum embraces General Capabilities that necessitate teachers working in a trans-disciplinary mode, but does not provide a flexible framework teachers can use to scaffold creative thinkers and learners. A creativity framework is essential for educators who are seeking pedagogical approaches that provide their students with the greatest probability of realising their creative potential (Gardner, 1997).

The fruits of creativity enrich our culture and improve the quality of all our lives. This paper explores the concept of creative minds in interaction, as opposed to creative minds in isolation from each other – from the *person-solo* to the *person-plus*. This is an important shift of focus in an age when networked collaboration for innovation is becoming central to how we live and work (DIISRTE, 2009). It takes the creative classroom discourse that draws connections between individual and collective creativity in classrooms and specifically addresses the question "what if education departments, schools and individual teachers had the confidence, capabilities and resources to optimise student creative potential?" It proposes a theoretical framework for *Distributed Creativity* in classrooms that can be used by researchers and educators to study and optimise student creative potential. The *Distributed Creativity* framework, we propose, provides a necessary link in the curriculum to classroom chain that will assist educators to create and evaluate innovative frontiers of teaching and learning in 21st century classrooms..

Creativity

Proctor (1999) and Proctor and Burnett (2002) concluded that, as with intelligence, many difficulties associated with research into creativity stem from the absence of an agreed definition. Creativity means different things to different people and confusion arising from failure to make the meaning explicit impedes communication. It is of paramount importance to formulate a clear and defensible definition of the construct upon which to base research and teaching. Hence, Distributed Creativity as proposed in this paper, inescapably deals with students, classrooms and learning and understands creativity to be the capacity of students to solve problems, or to devise ideas and products in collaboration, that are considered both novel and valuable by their teachers and peers. This definition confers a purposeful, everyday dimension to creative thinking which views it as a way of behaving towards particular tasks. Further, Gauntlett (2011, p. 218) describes everyday creativity as "a process which brings together at least one active human mind, and the material or digital world, in the activity of making something which is novel in that context, and is a process which evokes a feeling of joy".

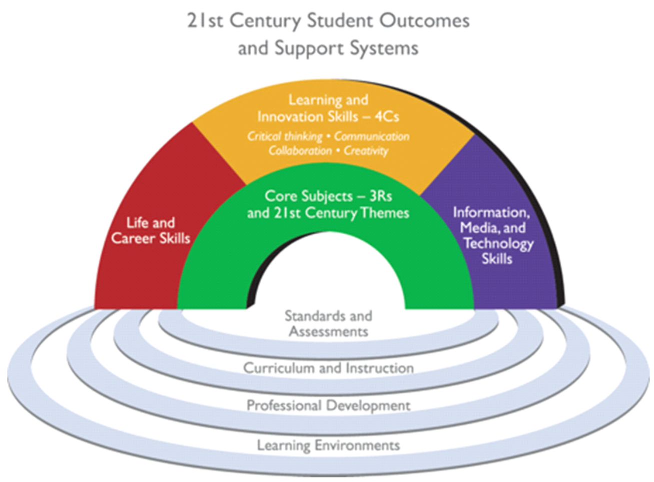
Research has only recently started to encompass the processes involved in creativity. Previous research has mostly sought to develop assessment measures to identify creative individuals. The most active areas of research have included personality traits of creative people; the relationship between intelligence and creative abilities; and the effects of various interventions on divergent ideation. Research has explored the lives of extraordinary individuals (Gardner, 1993a, 1997; Runco, 2007; Sternberg, 2002). Though this work adds to our understanding of the creative processes of outstandingly creative individuals, termed Big-C creativity, it fails to provide a coherent set of generalisations and a framework to underpin classroom research and pedagogy appropriate to the age and level of development of students. Our purpose in this paper is to articulate a theoretical framework to support the development of creative thinking in school students. The framework will describe the interaction among individual (personal student traits), domain (subject or content area) and context (both human and physical elements) and be based on the conjecture that meaningful, culturally valued creativity is distributed among individuals within a social context such as a classroom. However, the framework will necessarily view the creative process in classrooms in line with definitions of everyday creativity (Gauntlett, 2011) or what has been recently termed "little-c" or "mini-c" creativity, as opposed to "Big-C" (Beghetto & Kaufman, 2007; Runco, 2007). Both Big-C and little-c creativity rely on field judgments of novelty, appropriateness, and impact to validate the claim that the end products or artefacts are indeed creative. "Mini-c" creativity described by Beghetto and Kaufman (2007), however, highlights the important relationship between learning and creativity; the process of being and becoming creative. This dimension of creativity is therefore most appropriate when describing the developing creative thinking of school students. We contend that a theoretical framework is needed to allow researchers to examine the relationship between creativity and classroom learning, and the development of higher forms of creative expression. Such a framework should assist teachers to properly encourage and support mini-c creativity so that it can evolve into further creative pursuits that support a lifetime of creative learning and expression. The framework should support the development of pedagogical approaches that effectively enhance student creative thinking processes (mini-c creativity) in 21st century classrooms.

A systems perspective on creativity

In parallel with the increased attention that ICT has received in global education initiatives, the 4Cs are considered by many educators as essential knowledge and skills for every child to ensure they are prepared for the rigours of higher education, career challenges and a globally competitive workforce in the 21st century (Partnership for 21st Century Skills, 2011). The Partnership for 21st Century Skills (P21), an initiative of the US Department of Education, has created a conceptual framework (Figure 1) for 21st century learning.

The framework presents a systems perspective on 21st century teaching and learning that combines a focus on 21st century student outcomes (depicted by the arches) integrating a combination of specific skills, content knowledge, expertise and literacies, with innovative support structures (depicted by the radiating bands under the arches) to help students master the multi-dimensional abilities required of them in the 21st century. Creativity is clearly indicated in Figure 1, and widely accepted in the literature and schooling policy and curriculum documents from around the world, as a required 21st century student outcome from schooling (Australian Curriculum Assessment and Reporting Authority, 2011). However, what is

Figure 1. Framework for 21st Century Learning



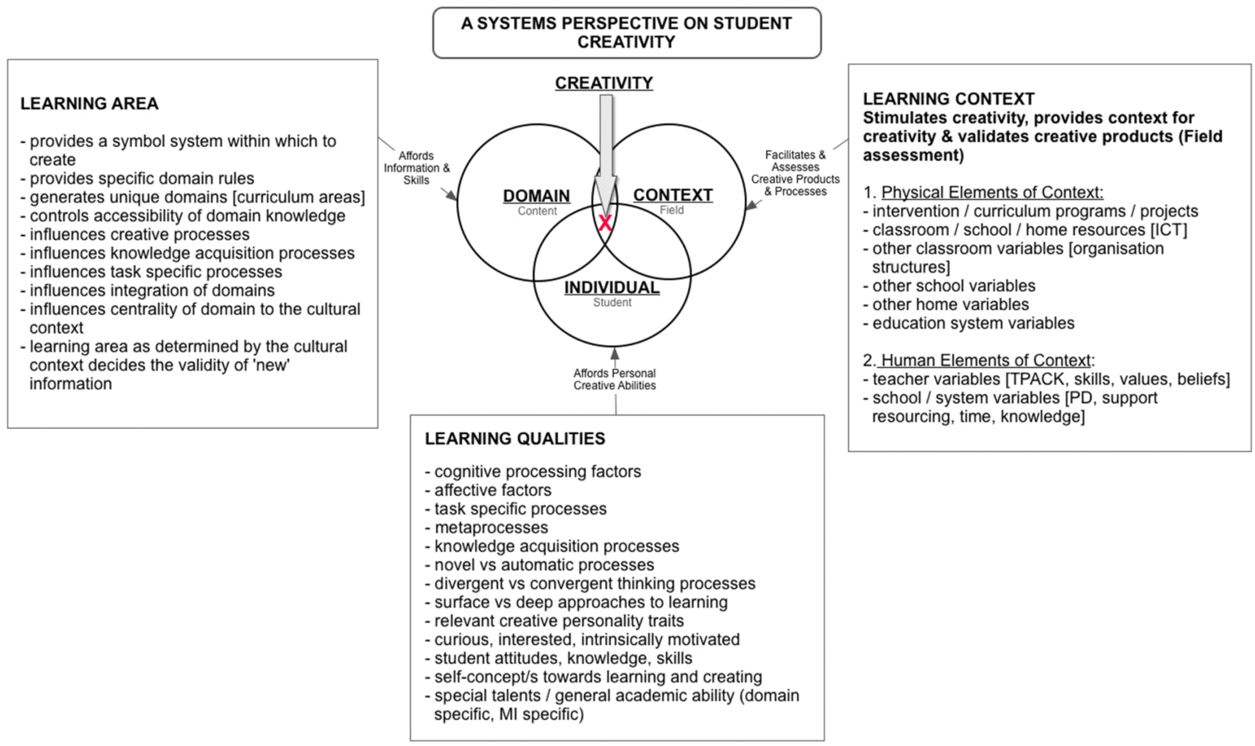
not clear in the literature is the way the four skill sets (Life and career skills, 3Rs, ICT skills, 4Cs) interact and are integrated in classroom teaching and learning contexts. Educators and researchers are increasingly interested for example in the possible transformative role ICT might play in attaining the learning and innovation skills depicted in the arches of Figure 1.

In the latter part of the 20th century, researchers proposed various systems perspectives for the study of creativity (Csikszentmihalyi, 1999). Such systems perspectives, or confluence approaches to the study of creativity, are based on the hypothesis that multiple components must converge for creativity to occur (Amabile, 1996; Csikszentmihalyi, 1996; Gardner, 1993b; Sternberg, 1996; Sternberg & Lubert, 1996). Csikszentmihalyi (1999) for example, highlights the interaction of the individual, the *domain*, and *field* as necessary to produce novel solutions. He argues that an individual draws on information in a specific domain or symbol system and transforms or extends this information through personal cognitive processes, personality traits, and motivation. The field consists of other individuals within a domain or context who evaluate and select novel ideas which they view as worthy extensions of the domain and which should be preserved and transmitted to other individuals, now and into the future.

In order to enhance and measure student creativity effectively, educators need a conceptual model that differentiates between important cognitive, dispositional and behavioural characteristics of the individual, and which also illustrates the interplay between these individual characteristics and the domain within which they are brought to bear, as well as the context (field) in which the individual is operating.

Figure 2 depicts a theoretical model, based on the creativity literature and an understanding of 21st century classrooms, which might guide educators and researchers in relation to enhancing and measuring mini-c student creativity. The model is not static as it represents a relational system where a change to one part of the system affects the other parts. It illustrates the interrelationship between the three major components (Individual, Domain and Context) with indicative specific creativity variables that should be considered. Further, the model will evolve as our understanding of the impact of constantly evolving digital devices on creativity develops.

Figure 2. A Systems Perspective for Student Creativity in Classrooms



The model depicted in Figure 2 identifies the main dependent variables in each of the three major components (Individual, Domain and Context) that are predicted to impact on school student creativity. These variables have been gleaned from the accumulated literature on creativity and are specific to learning contexts where students operate within, and manipulate the symbol system of a particular domain, all within a describable/observable learning context. Further, the model recognises that the students bring to bear their individual learner qualities to each learning task in order to create an innovative response that is validated by others (teachers, peers, parents/caregivers) who are also part of the context (field). Educators could use the model in order to plan appropriate, tailored learning activities for students, where for example they might be required to use their iPads and other digital technologies (laptops, desktops, wifi, apps etc) that are part of the classroom context, to create novel products in a specific learning area or a combination of learning areas. Researchers might use the model to develop observation tools and measurement instruments. Each of the three variable clusters (Learning Area, Learning Qualities, and Learning Context) could be the focus of classroom observations where students are expected to use digital technologies to create a novel response in collaboration with others, both within and beyond the physical classroom.

Assumptions upon which the systems model for student creativity in classrooms is based

This theoretical model is predicated on four assumptions. The first is that creativity research is a valid and valuable enterprise. Just as genetic variation gives rise to biological evolution, creativity engenders cultural evolution. Understanding creativity is a practical base upon which to build a sustainable Australian society in the Asian Century (Commonwealth of Australia, 2012). "Using creativity and design-based thinking to solve complex problems is a distinctive Australian strength that can help to meet the emerging challenges of this century" (Commonwealth of Australia, 2012, p. 2).

The second assumption is that creativity is not a personal dimension that resides solely within some exceptional individuals. The discoveries of any great creator, such as Einstein, would have been much less without his accumulated prior knowledge; without the intellectual and social network that stimulated his thinking; without the physical elements or tools he had available in his context at the time; and without the cultural mechanisms that recognised the value of his innovations. "To say that the theory of relativity was created by Einstein is like saying that it is the spark that is responsible for the fire. The spark is necessary, but without air and tinder there would be no flame" (Csikszentmihalyi, 1996, p. 7).

A comprehensive theoretical model of creativity in 21st century classrooms should include a study of the domain (a set of symbols, rules and procedures) and the context in which the individual student is operating.

The third assumption is that creativity arises from the interaction between a person and a particular sociocultural context. This implies a study of creativity as a system, asking not what is creativity, but more importantly, where is creativity? Csikszentmihalyi (1996), Gardner (1993b, 1997), Feldman, Csikszentmihalyi and Gardner (1994), and Perkins (1992) all concluded that an artefact can be termed "creative" only when it is delivered to field experts who give it their approval for recognition in a cultural domain. Thus, a combination of personal traits is not the determinant of whether a person is considered creative. What counts is whether or not the novel process or product is accepted for inclusion in the domain. Hence, the traits of personal creativity may help generate a novel idea or product, but the innovation will not be included in, nor bring about a cultural evolution to the domain, unless it is recognised as valuable by the culture. Primary students who are learning how to write or draw or invent, are probably not at the stage where their creations are going to be novel or useful to anyone else but themselves. Beghetto and Kaufman (2007) assert that people cannot normally be creative in a field without truly learning the field. Thus, they propose the construct of "mini-c" creativity to describe a process by which creativity develops; by which a person becomes creative. Mini-c creativity highlights the importance of skilled others (i.e., teachers) recognising the value of introducing novices (i.e., students) to the socially negotiated conventions, standards and existing knowledge of a domain. They maintain mini-c creativity is "its own unique process and merits its own unique standards that provide creativity researchers and educators with a new way of thinking about how creativity can be studied, understood and (ultimately) cultivated" (p. 77). The theoretical model for student creativity proposed in Figure 2 accepts the assertion that mini-c creativity offers the capacity for developing an understanding of how students discover and apply new insights and under what conditions such insights might develop into little-c and perhaps even Big-C creativity.

Finally, Perkins (1992) related the system model for creativity to learning in classrooms. He described the activity in most classrooms as "person-centric" where it is the "person-solo" who is expected to possess the knowledge, skill and creativity to complete tasks. This mode of operation – non-collaborative and without any physical and information tools - is rare in the modern world of work and life. People function in "person-plus" modes, using numerous physical and information resources, as well as interactions with other people to communicate and collaborate, frequently on a global level through social media. The person-plus concept implies both a team of people and a group of physical supports for cognition. Pea, Perkins, Salomon and others have investigated what they have termed "distributed intelligence" or "distributed cognition" or even "social creativity" (Fischer, 2000, 2004; Salomon, 1993; Watson, 2007). They all argue that human cognition at its richest almost always occurs in ways that are physically, socially and symbolically distributed.

Digital technologies and creativity

Evidence suggests that students' creative thinking can be facilitated and even significantly enhanced when they work collaboratively with access to appropriate digital technologies (Batham, Jamieson-Proctor, & Albion, 2014; Jamieson-Proctor & Larkin, 2012; Proctor, 1999; Proctor & Burnett, 2002).

The *Australian Curriculum: Technologies* (v8.1) (Australian Curriculum, 2016) encompasses two distinct but related subjects:

(1) Design and Technologies, in which students use design thinking and technologies to generate and produce designed solutions for authentic needs and opportunities; and

(2) Digital Technologies, in which students use computational thinking and information systems to define, design and implement digital solutions.

The overarching key idea in the *Australian Curriculum: Technologies* is 'creating preferred futures', placing creativity and innovation at the heart of the learning area. Its rationale states:

By applying their knowledge and practical skills and processes when using technologies and other resources to **create** innovative solutions, independently and collaboratively, they [students] develop knowledge, understanding and skills to respond **creatively** to current and future needs. The practical nature of the Technologies learning area engages students in critical and **creative** thinking, including understanding interrelationships in systems when solving complex problems. A systematic approach to experimentation, problem-solving, prototyping and evaluation instils in students the value of planning and reviewing processes to realise ideas. (Australian Curriculum, 2016)

The *Australian Curriculum:* Technologies aims to develop the knowledge, understanding and skills to ensure that, individually and collaboratively, students:

- investigate, design, plan, manage, **create** and evaluate solutions;
- are **creative**, innovative and enterprising when using traditional, contemporary and emerging technologies, and understand how technologies have developed over time;
- engage confidently with and responsibly select and manipulate appropriate technologies – materials, data, systems, components, tools and equipment – when designing and **creating** solutions; and
- critique, analyse and evaluate problems, needs or opportunities to identify and **create** solutions. (Australian Curriculum, 2016) The overarching key idea, rationale and aims of the *Australian Curriculum: Technologies* repeatedly foreground creativity; as evidenced by the bolding in the direct quotations above. There is obviously an expectation that teachers from Foundation to Year 10 in all Australian schools will provide students with opportunities and resources, including digital tools, with which to express and enhance their creativity. The inclusion of 'design thinking' among the other key ideas in the curriculum should encourage teachers to engage students in the design cycle of investigating needs in their context, generating possible solutions, selecting and implementing a solution, and evaluating its effects as foundation for further rounds of the cycle. Although design and creativity are not synonymous they are closely related and immersion in the design cycle will provide students with opportunities for creativity in which the products have the characteristics of creative output, novelty and utility in context, that clearly match the requirements of everyday creativity (Gauntlett, 2011; NACCCE, 1999). In recent years all developed countries have witnessed a surge in the availability and appropriation of powerful, and more and more mobile, digital technologies in classrooms. It has been suggested by many researchers that a lack of both technical knowledge and pedagogical knowledge has contributed to a limited success with digital technologies in classrooms (Batham et al., 2014; Cuban, 2000, 2001). While the uses of ICT to support and promote creativity have been described, reviewed and theorised in a number of research studies, and a conceptual framework for creativity and ICT in primary classrooms has been proposed (Loveless, Burton, & Turvey, 2006), the understanding and implementation by educators of the practicalities of enhancing creativity with ICT need further explication. A theoretical framework for creativity in 21st century, technology-rich classrooms should take account of the literature with respect to creativity, particularly mini-c creativity (Beghetto & Kaufman, 2007), and describe the interaction between individual, domain and context, so that ICT might be used to support creativity through encouraging learners to make curriculum connections, develop personal creative abilities and dispositions, create meaning, collaborate and communicate.

Summary

The current climate in Australian schools is favourable for creativity as evidenced by the expectations in the *Australian Curriculum: Technologies*, but teachers and researchers require the theoretical tools with which to critically analyse the affordances of ICT to promote substantial creative experiences for students. Teachers also require practical approaches to including creativity that remove the burden of recognition by domain experts imposed by the prevailing understanding of Big-C creativity. The ideas around everyday creativity

(Gauntlett, 2011) and mini-c creativity (Beghetto & Kaufmann, 2007) can liberate teachers and students from the constraints of Big-C creativity and a focus on design can provide a practical approach to creative work in the classroom. So in seeking to answer the question "what if education departments, schools and individual teachers had the confidence, capabilities and resources to optimise student creative potential?" we have proposed a theoretical framework for *Distributed Creativity* in classrooms for educators to optimise student creative potential (Figure 2). We believe the *Distributed Creativity* framework provides a substantial link in the curriculum to classroom chain that will assist educators to better understand and enhance the creative thinking of students in 21st century classrooms.

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Lisa Wicks

Lisa Wicks teaches Design and Technology and Information Software Technologies in years 7-12 at at Kambala, a K-12 girls school, in NSW. Lisa has been teaching in this field for over 10 years, and in 2016 started a Masters of Education (Digital Learning) at Monash University. An increasing interest in emerging technologies and their potential for learning and education has lead Lisa to develop this Augmented Reality project, as part of her studies in the Master of Education program at Monash University.

Introduction

The purpose of this project was to explore the possibilities of augmented reality in a Design and Technology (DT) classroom and develop an instructional product that would be immediately useable in context, providing an authentic exploration of using this technology in the classroom. Augmented Reality (AR) uses technology to overlay data onto real-world views through devices eg tablets or smart phones, or headgear such as the Microsoft Hololens, or Google Glass. The most widely known, or commonly used example of AR is the game Pokemon Go, although, AR is also being used more frequently now for educational purposes, allowing students to access and interact with knowledge that may not be possible without this technology.

Initially, I analysed the context and specifications of the project, the proposed design brief, and a justification of the key project elements:

- Potential of augmented reality
- Need for reinforcement of learning
- Resource Content: Machine Safety and Operations, and
- The DT classroom context

Detailed Context and Specifications

Students (in year 7-12) in Design and Technology complete design projects that require the use of different machines in a workshop, including a scroll saw, drill press, buffing machine, sanding machines, and sewing machine. Students are instructed in the operations and safety requirements for each machine prior to its use, but often forget the details during a project and repeated instruction is required. A resource utilising augmented reality technology, such as a poster, could benefit students by enabling them to independently review the safety and operations of each machine. A further benefit would be to the teachers, enabling their time to be used to aid students in developing the complexity of their skills and quality of design projects, instead of restating basic preliminary knowledge. Based on these specifications, I developed the design brief following.

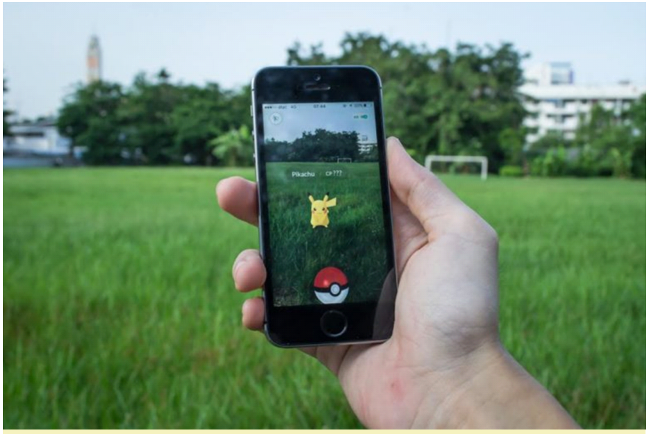
Analysis and Justification of the Design Brief

The Design Brief:

To design and create an instructional resource that utilises augmented reality to reinforce the learning of safety and operations of machines in the Design and Technology Classroom.

Augmented Reality (AR) Potential

AR is poised to become a widely-used technology, infiltrating our everyday lives, with greater impact and value to users than the initial novelty and hype of new technologies. Already, AR is being employed for advertising such as the Pepsi Max "Unbelievable Bus Shelter" Campaign (https://www.youtube.com/watch?v=Go9rf9GmYpM, PepsiMax, 2014), and for entertainment, for example, Disney's AR Colouring Book, and the game Pokemon Go which has brought AR into mainstream attention with its viral success (Gstoll, 2016).



A love letter from augmented reality to Pokémon Go (Gstoll, 2016)

Whilst these applications of AR will become more prevalent, the potential in education is immense. This is especially true with greater availability of mobile technology providing the capability of accessing and authoring AR content, AR will soon become inseparable from daily activities (Chi-Yin Yuen, Yaoyuneyong, & Johnson, 2011). Thus, exploration of the educational potential of AR is essential. Wu, Lee, Chang, & Liang (2013) state that "the educational values of AR are not solely based on the use of technologies but closely related to how AR is designed, implemented, and integrated into formal and informal learning settings" (p.41). Therefore, careful design and planning will be required to successfully support learning in the identified context.

Furthermore, educational research points towards increased engagement and efficacy of learning when AR is utilised compared with other computer-based technologies, and that students overall have an increased understanding of content, improved spatial understanding, improved physical task performance and increased motivation (Radu, 2014).

Whilst AR will be explored further, this brief introduction justifies AR as an appropriate medium to use in this project.

Reinforcing Learning - Current Issues

The purpose of the instructional resource was to reinforce safety and machine operations demonstrations provided by the teacher in the classroom.

Issues I have encountered include:

- Limited space for students to view details in demonstrations
    - Inhibits sensory input required for effective information processing.
    - Environmental and social distractions may contribute to poorly focussed attention and failed transfer of information to long-term memory (McInerney, 2014).
- Students forget demonstration content
    - Content has not been presented in a way to enable successful encoding of information and transference.
    - Lack of meaningfulness, complexity or length of content may contribute (McInerney, 2014).
- Limited time for repeating information
    - Lessons time could be used more effectively.

In my classroom, I had identified the need for an instructional resource that reinforces demonstrations.

Resource Content: Machine Safety and Operations

The importance of safety in the DT classroom is paramount as teachers have a responsibility for the safety of students in their classroom. This justified by legislative, and NSW Board of Studies (BOSTES) curriculum requirements. Proper instruction in machine operations will enable students to participate safely in classroom activities and develop skills towards producing high-quality designs (an essential component of learning within DT, as well as an assessable skill).

The Research section examines the specific details required by Work Health and Safety Legislation and relevant syllabus requirements that support the need for this content.

DT Classroom Context

Having been a DT teacher for over ten years, it is a context with which I am very familiar. Physical access to the space and pre-existing knowledge of machinery use and safety instruction provides the opportunity to develop an authentic product.

Research

In this section, four areas of research will be explored:

1. Analysis and discussion of the potential and challenges of AR in education,
2. Context investigation and analysis of staff survey,
3. Summary of Work, Health and Safety (WHS) legislative requirements, and
4. Summary of the NSW Board of Studies (BOSTES) curriculum requirements.

This research will direct decisions for content and structure of the resource.

AR: Potential Opportunities and Challenges

Defining AR is a critical in determining the best way to utilise this technology in the identified context. The clarification of this term will lead into a discussion of educational research and provide a sound basis for decision-making throughout this project.

AR has been defined in research in several ways. At its' core, as a computer generated, enhanced experience of real environments (Lee, 2012). Klopfer (2008, as cited by Wu et al., 2013) similarly suggests a broader definition as "any technology that blends real and virtual information in a meaningful way" (p. 42). Furthermore, Azuma (1997, as cited by Wu et al., 2013) introduces instantaneous interactivity and 3D synthesis of real and virtual components. The level of blending between real and virtual can be determined by the purpose of the educational resource and how the technology can best be used to meet the needs of the learner. Milgram, Takemura, Utsumi and Kishino (1994) explore the implications of the term AR, proposing a continuum of mixed reality displays from AR to Virtual Reality, relating to the proportion of the "real world" visible in the user's display. Examining this continuum was useful in determining how immersive my AR product should be.

Billinghurst, Grasset & Looser (2005) suggest that the close relationship between physical and virtual components allows an opportunity to design an AR interface providing familiarity for users. Ensuring the correct balance between real and virtual objects is essential to encourage connections between the learner and content. McInerney (2014) asserts that meaningful material is easier for learners to process, and from the perspective of Information Processing theory, encourages deeper retention of information. In this way, greater success will be achieved by creating lightly augmented resources for this project, as the environment will contain a higher proportion of real components, with greater familiarity to the user. This will directly relate to the design of the interface and, as Billinghurst et al., (2005) suggest, will need to consider the physical components, audio-visual elements, and the interactions that connect them.

Opportunities for AR in educational settings are rapidly emerging as technology becomes more accessible. Azuma, Billinghurst, & Klinker (2011) suggest that recent development of mobile technology provides educators with powerful AR hardware platforms; thus encouraging developers to create AR authoring tools such as Aurasma, Layar, Blippar and ZapWorks. I investigated these software platforms for their potential suitability for this project based on ease of use, functionality, and cost. Lee (2012) confirms that educational settings are ripe for using mobile technology for learning via AR integrated experiences and iterates AR projects in various science and mathematics subject areas. Possibilities exist to create valuable and engaging learning experiences in the DT subject area. Furthermore, the use of handheld devices increases experiential authenticity within the classroom environment as being less intrusive than head-mounted devices (Klopfer & Sheldon, 2010, as cited by Wu et al., 2013). The software identified above all enable access via mobile devices, and function across both Mac and PC operating systems, ensuring flexibility in the classroom.

AR operates via a markerless or marker-based operation to activate augmented components of a product. The software identified above use a variety of these in their platforms. Aurasma, Blippar and Layar operate as markerless AR, that is, they use image recognition, GPS or accelerometer data to engage interactive content.

Marker-based AR products are tagged with a unique target image that is recognised by the device's camera to activate the AR content (Albright, 2015). There are advantages and disadvantages to both types of AR for this project. Zapworks (2016) promote several advantages to a marker-based AR including:

- recognisable icons informing users of AR content
- simple, without reliance on potentially unsuccessful image recognition
- icons can be re-used on different product

Disadvantages of AR markers include:

- marker icons may not scan easily if they are too small or become damaged
- may not fit the design of the product, or visually disrupt product aesthetics
- different developer platforms use different markers and are not interchangeable
- rely on the use of a specific app to be downloaded onto the user's mobile device

("Markerless Augmented Reality - ARLab Blog", 2016)

Selecting a marker-based AR platform may be advantageous for this project as students will be able to clearly identify the AR components and similarly if AR is to be used in future educational resources, they will have developed that familiarity. The ability to re-use icons will be another advantage to choosing a marker-based style as the design of the page could change slightly in future, however, the AR component could remain the same, enabling future-proofing and saving time building subsequent resources.

There are many challenges of using AR in education and Wu et al., (2013) suggest three domains: Technological, Pedagogical, and Learning.

Technological issues include the bulky and expensive nature of head-mounted-display units, instability of AR between devices, and location dependency. These issues will be mitigated in this project by the use of mobile devices instead of head-mounted units as Wu et al., (2013) reason, including cost, but also the lack of accessible technology. A head-mounted unit would also present significant safety risks in a workshop, where an immersive device would impede students' physical awareness. The use of a multi-OS development app will help alleviate any issues arising from students having varied devices. Finally, the location dependency, while not relying on GPS data, the students will need to be close to the posters to initiate AR content. This will impact the poster placement within the classroom, to ensure they are close-by the relevant machine, however, not impacting on its' safe use.

Pedagogical issues discussed by Wu et al., (2013) refer to push-back from communities from using new technologies, content design and delivery, and inflexibility of content design in AR. As AR is becoming more commonplace, I believed that stakeholders will be excited by this project; already this is true from anecdotal evidence. Furthermore, a small-scale, low-risk introduction will ensure a greater likelihood of acceptance. Content design was carefully considered to ensure the correct balance of elements within the resource. Whilst inflexibility of content was a concern, the safety and operational requirements for the various machines will not change over the near future, therefore this is not significant.

Learning issues identified by Wu et al., (2013) include concerns of cognitive overload, and abilities requiring the need for scaffolding. This will guide content design and will be further examined through the Final Design development section.

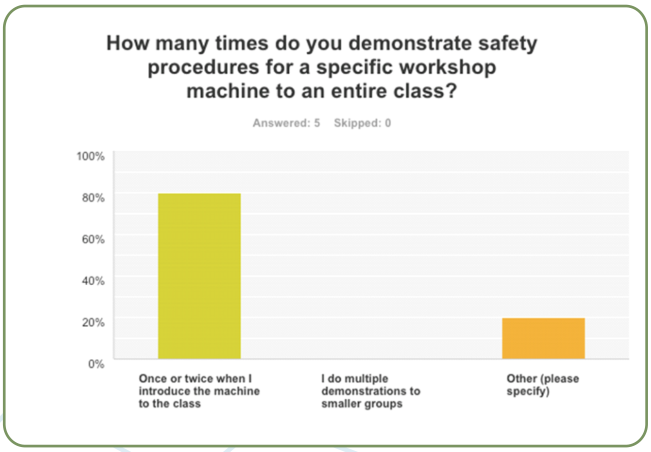
Context Investigation and Staff Survey

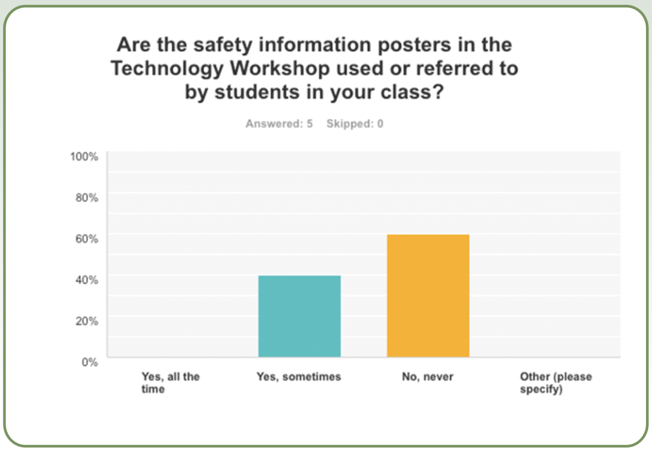
Data Collection

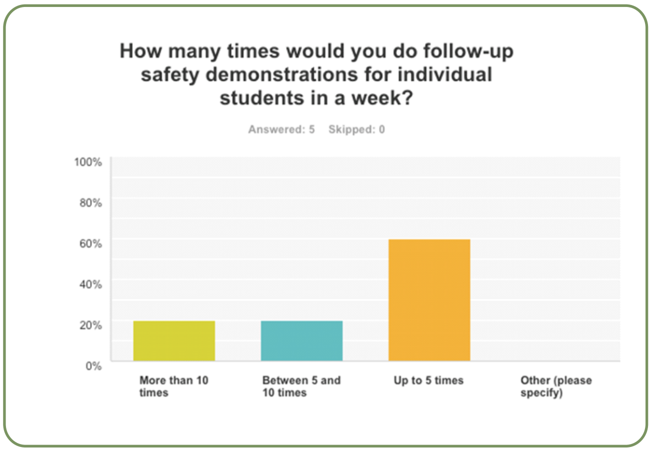
I had identified the need for this project based on personal experience and was interested if other teachers were having similar experiences. This would highlight a broader need and authenticity for this project. I conducted a short survey to ascertain this information and inquired on the following topics:

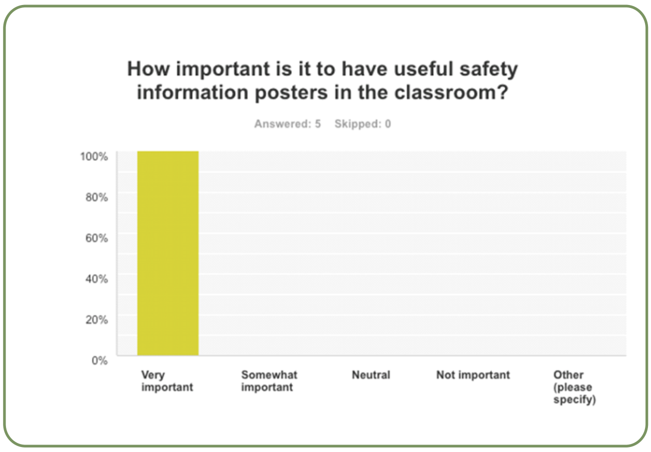
- usefulness of current safety posters
- mode of instruction for safety and operations
- level of repetition of instruction
- criteria of an interactive resource

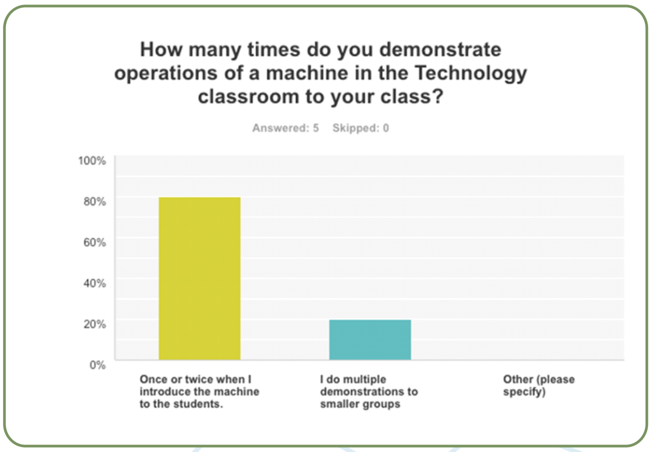
The survey consisted of ten multiple-choice questions, with optional comment areas for teachers, and was administered through Survey Monkey. There are 5 teachers in the faculty and each of them responded once. The questions and graphs of responses are shown below.

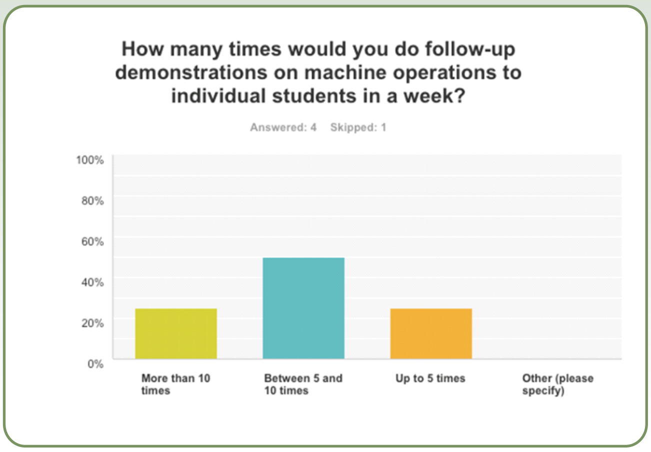


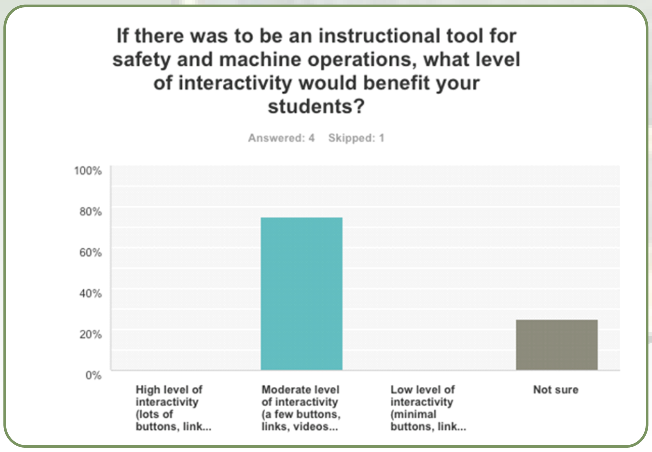


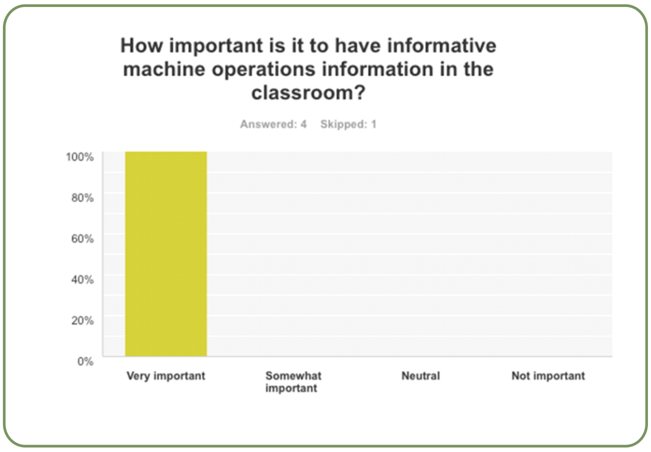


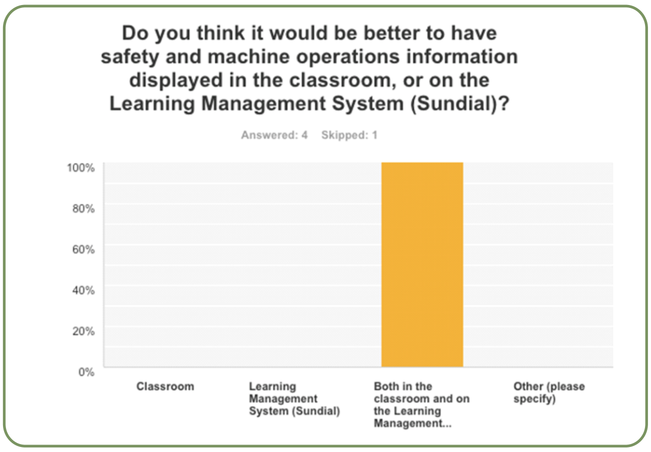


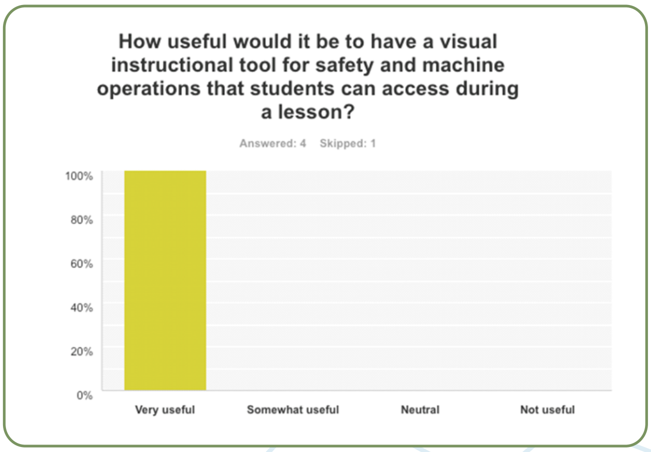












Data Analysis

I concluded that the other teachers had similar experiences regarding the safety and operation instruction. All teachers repeat demonstrations for both safety and operations with the majority instructing the entire class. One teacher commented that they present both small group and whole class instruction, though this included multiple repetitions. Similarly, follow-up instructions were repeated up to five times for both safety and instruction, however, the majority of teachers responded that they repeat operations more frequently, between five and ten times. Some teachers referred to the current posters, though more responded that they never refer to the safety posters. Unanimously, the teachers indicated the considerable importance of availability of safety/operations information in the classroom. Similarly, all teachers wanted to have the information on the current LMS platform. Finally, 100% of teachers felt that a resource of this kind would be very useful, and the preference was for a moderate level of activity. This confirms previous research stating the level of augmentation to be light.

Concluding Statements:

- Teachers are spending a large amount of time repeating instructions
- There is a greater need for operations content over safety content
- It is essential to have safety/operations information visible in the classroom
- Information must also be on the LMS platform, enabling students to access the resources when out of the classroom.

Work Health and Safety Legislation

A review of the Work, Health and Safety Act (WHS) 2011 (NSW) yielded the following essential conclusions:

Teachers must provide students with:

- physical demonstrations of safety requirements and machine operations

- training and instruction (can be in the form of supporting resources)
- safe working environment including access to Personal Protective Equipment (PPE)

Students are responsible for:

- taking reasonable care with their own safety and that their actions do not adversely affect the safety of others
- comply with instructions provided regarding safety

These points fall under the following sections of the WHS Act:

- Part 2, Division 2, Section 19: Primary Duty of Care
- Part 2, Division 4, Section 28: Duties of workers

Furthermore, Safe Work NSW provides guidance under the WHS Act 2011 (NSW) and the WHS Regulations 2011 (NSW) regarding the necessity for Personal Protective Equipment (PPE). This is one of the main safety considerations in the classroom, therefore, it was essential to include PPE content of this project.

Selecting safety content carefully was necessary to ensure that legal obligations were met under WHS legislation, though the primary source of safety instruction would be the teacher. Considering survey feedback from the teachers indicated safety instruction as a secondary purpose of the resource fitting well with the legal requirements of instruction and monitoring as prescribed above.

NSW Board of Studies (BOSTES) Requirements

To succinctly report the syllabus requirements, I focussed on the Year 7 and 8 Technology (Mandatory) course. The syllabi for years 9-12 follows a continuum with increasing sophistication of core concepts. Additionally, the machine requirements are consistent, and targeting the language towards the youngest users would ensure that terminology and information would be accessible to the majority of students using the posters.

Syllabus Objectives

Students develop:

- skills in the generation of creative design solutions
- understanding and skills for the safe use of tools

The table below identifies the key syllabus outcomes and course content that needed to be addressed by this project. The highlighted keywords indicate the main elements that were addressed in the resource developed. These keywords were selected based on relevance to WHS requirements, and analysis of staff survey.

Outcomes	Context
4.3.1 applies a broad range of contemporary and appropriate tools, materials and techniques with competence in the development of design projects	Students learn to: • select and **correctly use appropriate tools** and equipment for a design project • select and **use techniques** appropriate for the purposes of a design project (Technology (Mandatory) Years 7–8 Syllabus, 2003, p. 39)
4.3.2 demonstrates responsible and safe use of a range of tools, materials and techniques in each design project	Students learn to: • **manage risk** when developing design projects • **use tools**, materials and techniques in a responsible and safe **manner** in each design project. • **maintain tools** and equipment (Technology (Mandatory) Years 7–8 Syllabus, 2003, p. 24)
4.5.2 produces quality solutions that respond to identified needs and opportunities in each design project	Students learn to: • **identify** suitable materials, **tools and techniques** for each design project • practice and **refine skills** needed for design projects (Technology (Mandatory) Years 7–8 Syllabus, 2003, p. 25)

Ideation

This section communicates my ideas development based on research conducted previously regarding content and purpose of the resource, and incorporating research on content design.

I also explored the following:

- Design criteria - determining the elements required for a successful product
- Design constraints - identifying the restrictions or limitations for the project
- Ideas generation - demonstrating initial ideas and refinements to a final design concept

Design Criteria

Function:

- Effectively convey the required content using strategies like chunking, and scaffolding, as McInerney (2014) suggests, to provide more manageable pieces of information and build up levels of complexity
- Meaningful without added AR content so that students viewing the poster may increase their understanding of the machine prior to engaging with the AR content
- Use familiar terminology to activate prior knowledge, assisting in developing meaningful links between the student and content will increase learning potential (McInerney, 2014).
- Navigation structure should be consistent to promote ease of use. Predictable placement of features and elements across the posters will unify the collection, encouraging easier assimilation of knowledge.
- Manage cognitive load by providing multi-modal forms of instruction, but limiting competition between too many elements to avoid information processing failure.

Aesthetics:

- Prominence of features like buttons will ensure ease of use as these features will be correctly interpreted by the student (McInerney, 2014).
- Use familiar symbols to activate prior knowledge, similar to terminology above. An example might include standard PPE symbols as determined by the International Organization for Standardization (ISO) as these symbols are recognised worldwide.
- Design the content using the elements and principles of design and PARC principles will help create an aesthetically pleasing product.

Design Constraints

Time:

- Limited time to complete this project means the scope will need to be reasonable to be able to be achieved by the due date
- Due date: 10th October 2016 - updated to 17th October 2016 (26/9/16)

Finances:

- Minimal additional finances available meant development software either needed to be free to access or cost a minimal amount to create the product
  - Blippar has a free education account
  - ZapWorks has a personal account option that is initially free however an additional charge is required for continued use. Different software options allow varying degrees of sophistication in AR development.
  - Aurasma is free but has limited functionality appropriate to my needs
  - Layar is free to create but publishing incurs a hefty charge per page.

Practical Skills:

- I have strong graphics skills and have used the Adobe Creative Suite successfully (predominantly Photoshop and Illustrator) however, I have limited experience in 3D graphics, apart from SketchUp, and limited experience with advanced coding/scripting. Therefore, a solution will need to be developed where I can take advantage of existing skills.
- It will not be possible to produce a high-end, professional AR product that requires sophisticated 3D graphics skills or coding.

Ideas Generation

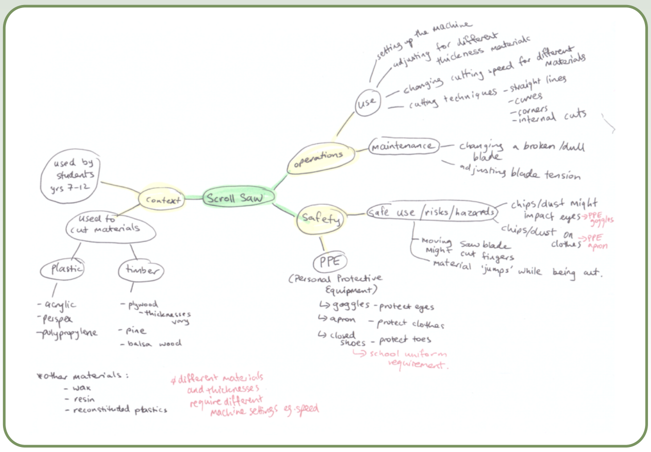
Brainstorming of Ideas

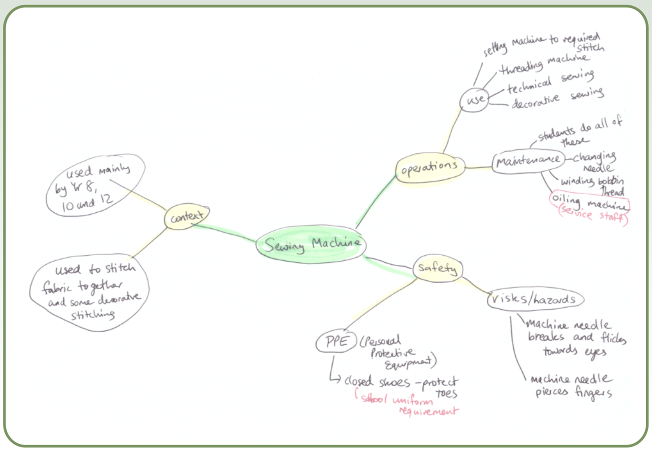
Initially, I identified five machines that might be addressed in this project. I completed a mind map for each machine, identifying its' context in the classroom, safety, and operations content. The points on each mind map were considered in response to research and survey data.

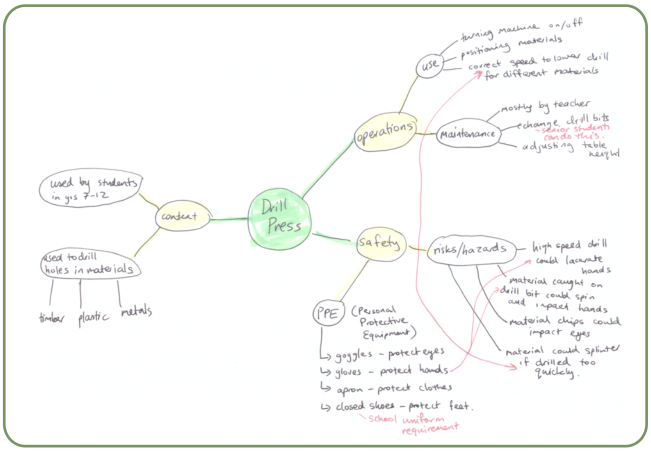
These maps highlighted key areas of content that needed to be addressed for the poster of each machine and I started formulating ideas for how each one might be approached in the product.

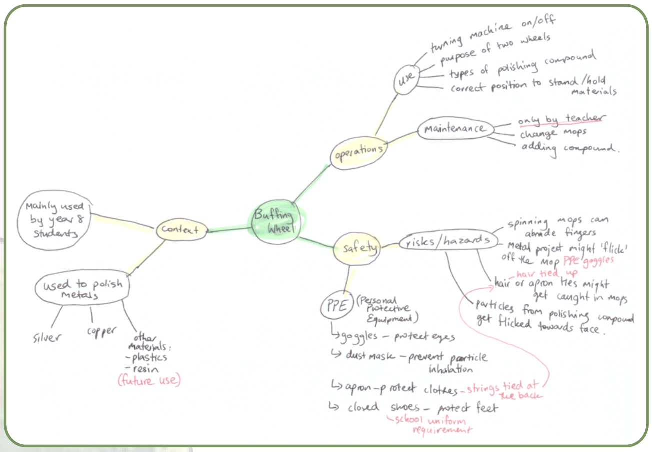
For each machine, I needed to address:

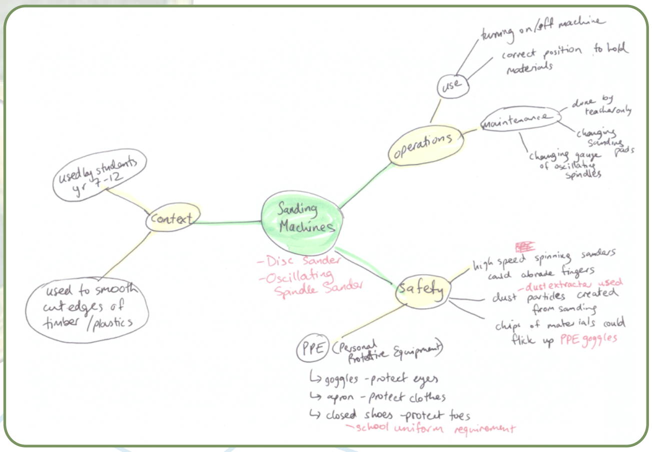
- how to set the machine to the correct settings
- how to operate the machine for different purposes
- maintenance skills required by the students
- PPE required





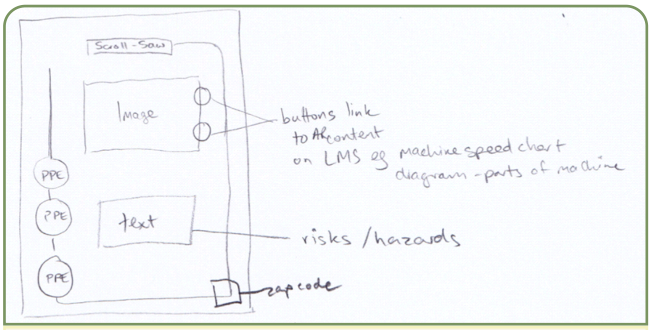




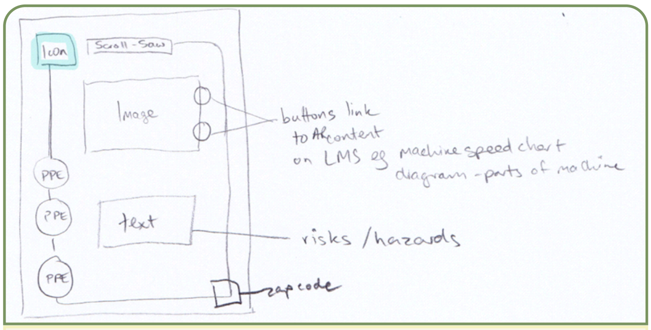


Design Sketching

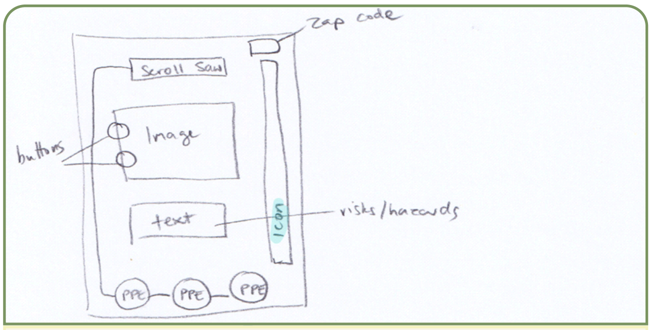
Initial idea sketches highlighted the need for machine-specific icons, which, in turn, dictated design decisions. Consideration of the elements and principles of design aided in the selection and placement of elements such as headings, buttons, images and text, as well as the AR specific identifiers (ZapCode).



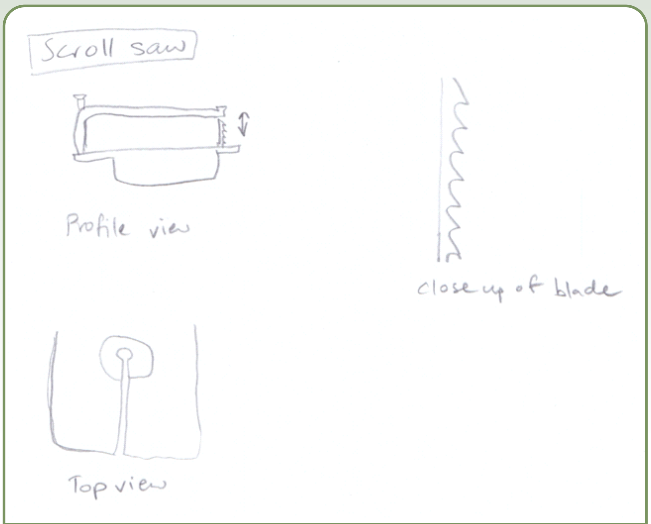
Design Idea 1



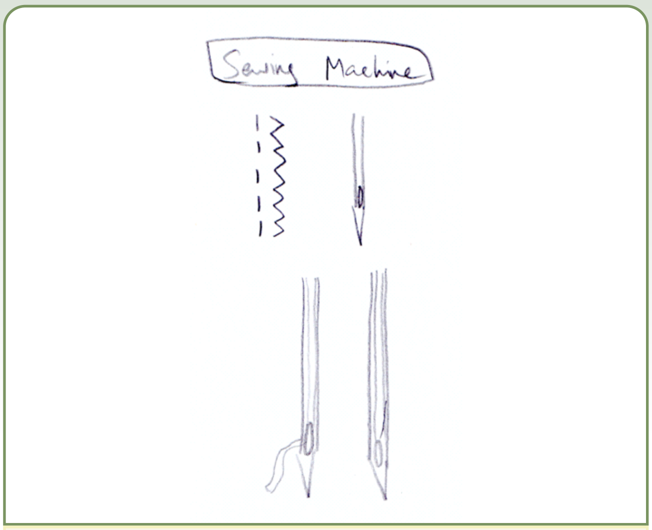
Design Idea 2: Added icon to the design to visually indicate the tool.



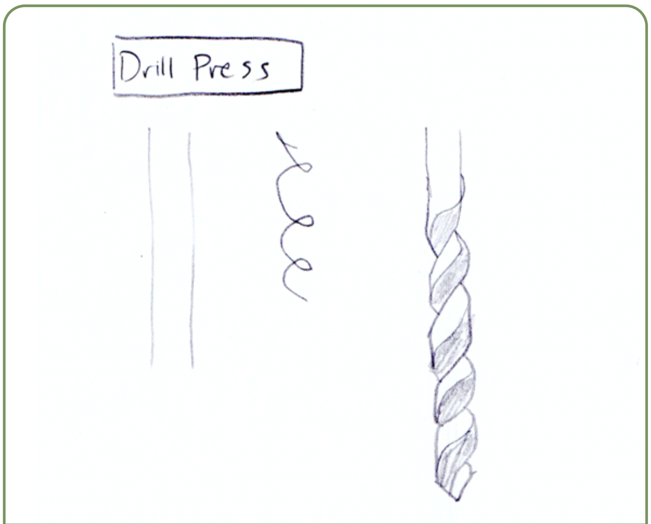
Design Idea 3: Icon location changed to a strip style incorporated into the border.



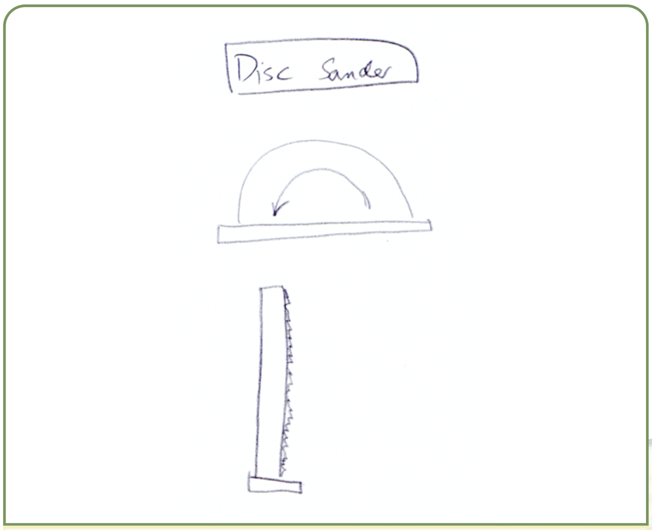
Icon Designs – Scroll Saw: Profile and top view are not as recognisable as the blade close-up. Acts as an immediate visual reminder of blade direction in machine.



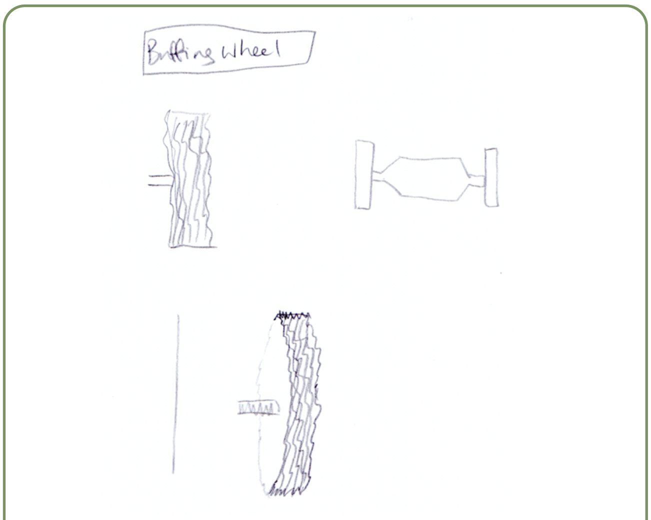
Icon Design – Sewing Machine: Stitch icons are recognisable, but add redundancy as they are pictured on the machine itself. The needle icon identifies a higher priority safety risk.



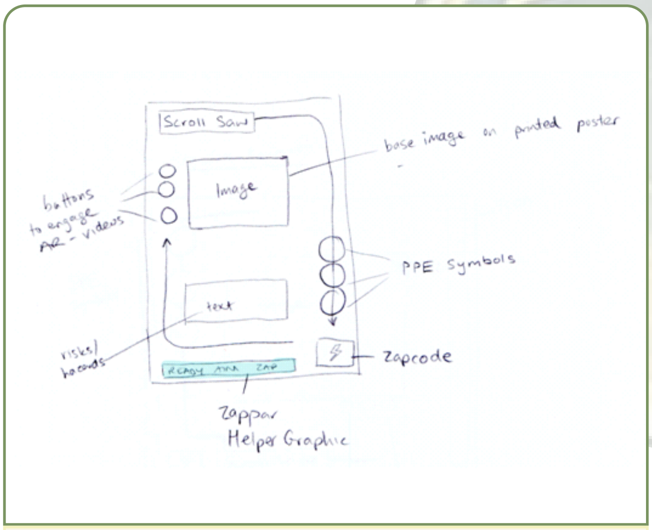
Icon Designs – Drill Press: Drill Bit icon as similar to Scroll Saw, using the "cutting implement" as an icon acts as a visual safety reminder.



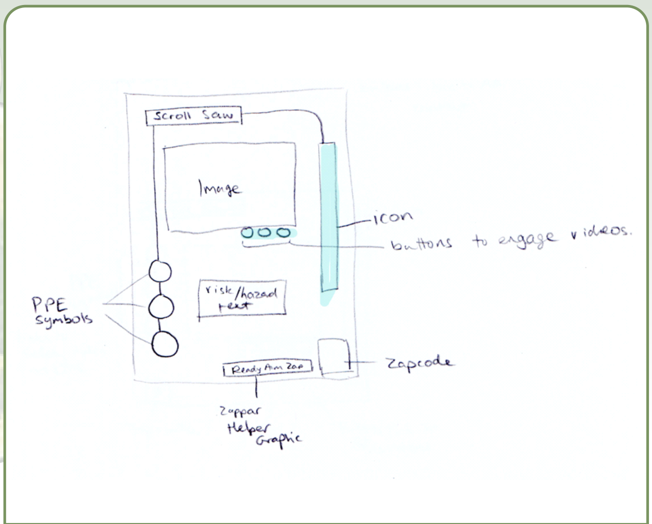
Icon Design – Disc Sander: Similar to other icon designs, the profile view acts as a safety reminder.



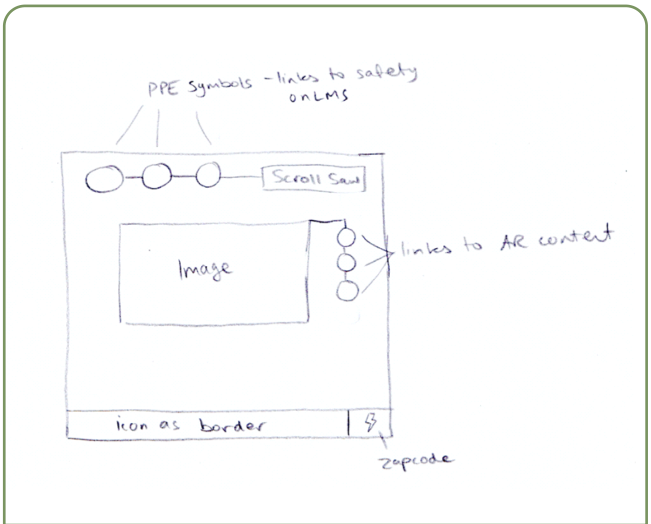
Icon Design – Buffing Wheel: Front view is more recognisable than profile view, however the profile highlights the abrasive surface as a safety reminder.



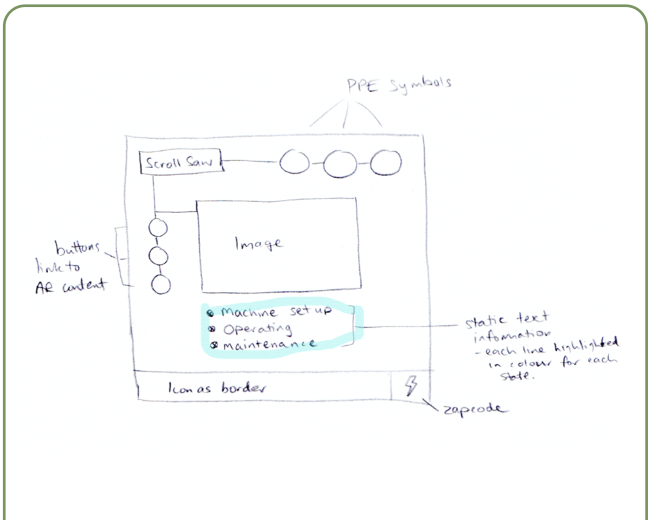
Design Idea 4: Added Zappar's "Helper Graphic" to assist users in activating AR content.



Design Idea 5: Added icon to the border and reduced size of helper graphic to minimise visual disruption.



Design Idea 6: Orientation of poster changed, icon at lower border and removed static text to reduce visual clutter.



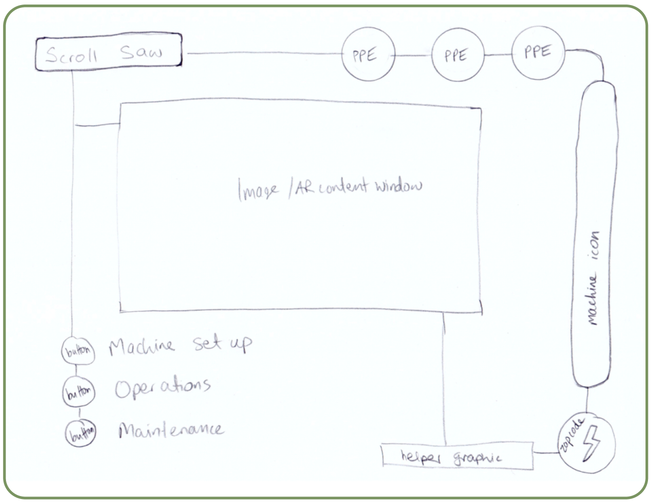
Design Idea 7: Static text revisited as headings for information that can be accessed in AR content.

Final Design

This section communicates the final design and some prototype development, justifying design decisions based on research of content design, colour theory, and cognitive load theory.

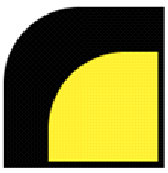
Final Design Sketch

The final layout of the poster is demonstrated for the Scroll Saw machine, however, all machine posters would follow the same format. This rough sketch was used to formulate the final product.

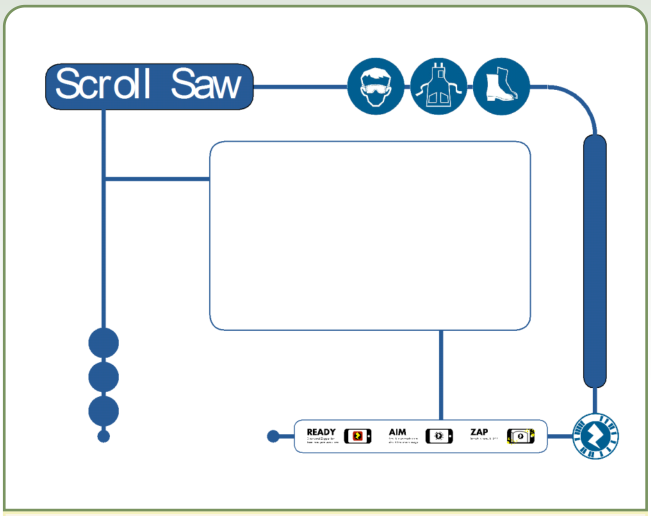


Colour Experimentation

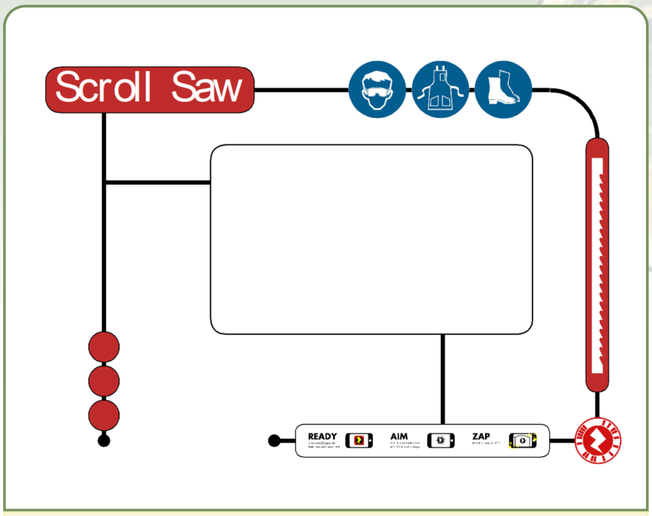
I used Adobe InDesign CC to create the layout for the poster and test colour combinations. Swatches are shown below with justifications of choices. A gallery of layout colour tests follows.

	Blue/White is consistent with mandatory PPE symbols and was selected to maintain consistency between elements, creating a cohesive design. Colour theory suggests blue to be a calming and non-threatening colour (Elrick, 2016) making it appropriate to encourage calm feelings in the workshop.
	Black/Yellow follows safety posters already used in workshops and WHS mandatory caution signs. Therefore, it is recognisable as a safety information source. Black promotes feelings of power and authority, whilst yellow, according to Linchpin SEO (2016) stimulates mental processes and activates memory ("Psychology of Color Guide For Designers [INFOGRAPHIC]", 2016).
	Red signifies danger (Elrick, 2016), and the Red/White combination is currently used in WHS mandatory warning signs. As such, it may provide confusion to the students as the purpose of the poster is for instruction, rather than alerting the user of impending danger.

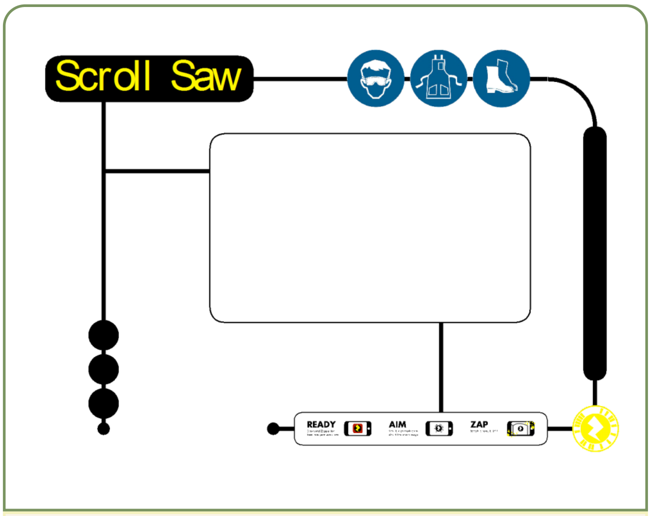
Colour Mockups



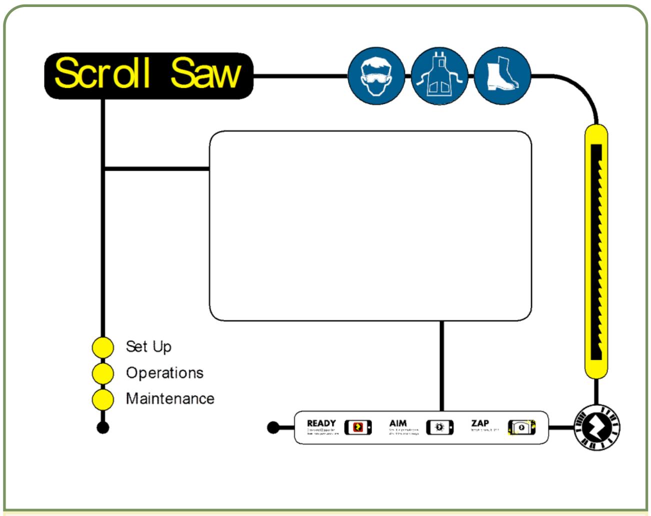
Blue Scheme: A consistent aesthetic but no contrast in colours. This makes it difficult to mentally organise groups of elements, restricting functionality of navigation.



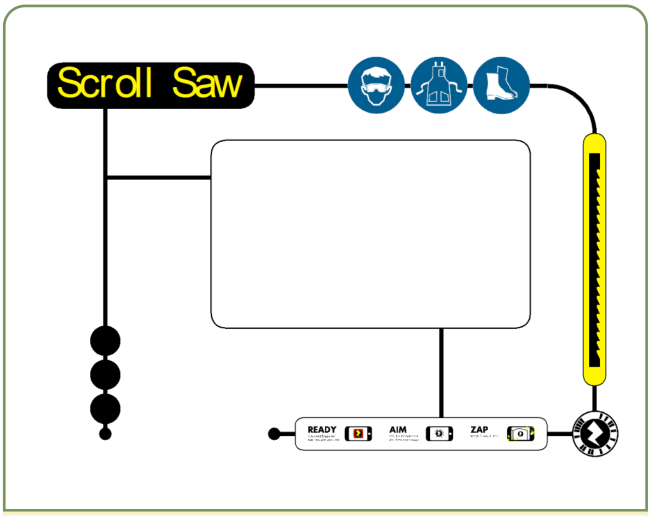
Red/White Scheme: Red stands out and attracts attention from the learner, but is perhaps too distracting. The combination of red, white and blue (PPE symbols) gives an undesired aesthetic.



Black/Yellow Scheme 1: Too much black in this version makes it heavy to view, and creates an imposing look. The yellow ZapCode does not have enough contrast to be functional. The title stands out and attracts attention.



Black/Yellow Scheme 3: Further modifications to the Black/Yellow design include yellow buttons, lightening the design and increasing contrast. Also, placement of left elements shifted further left increases white space and balance in the design.



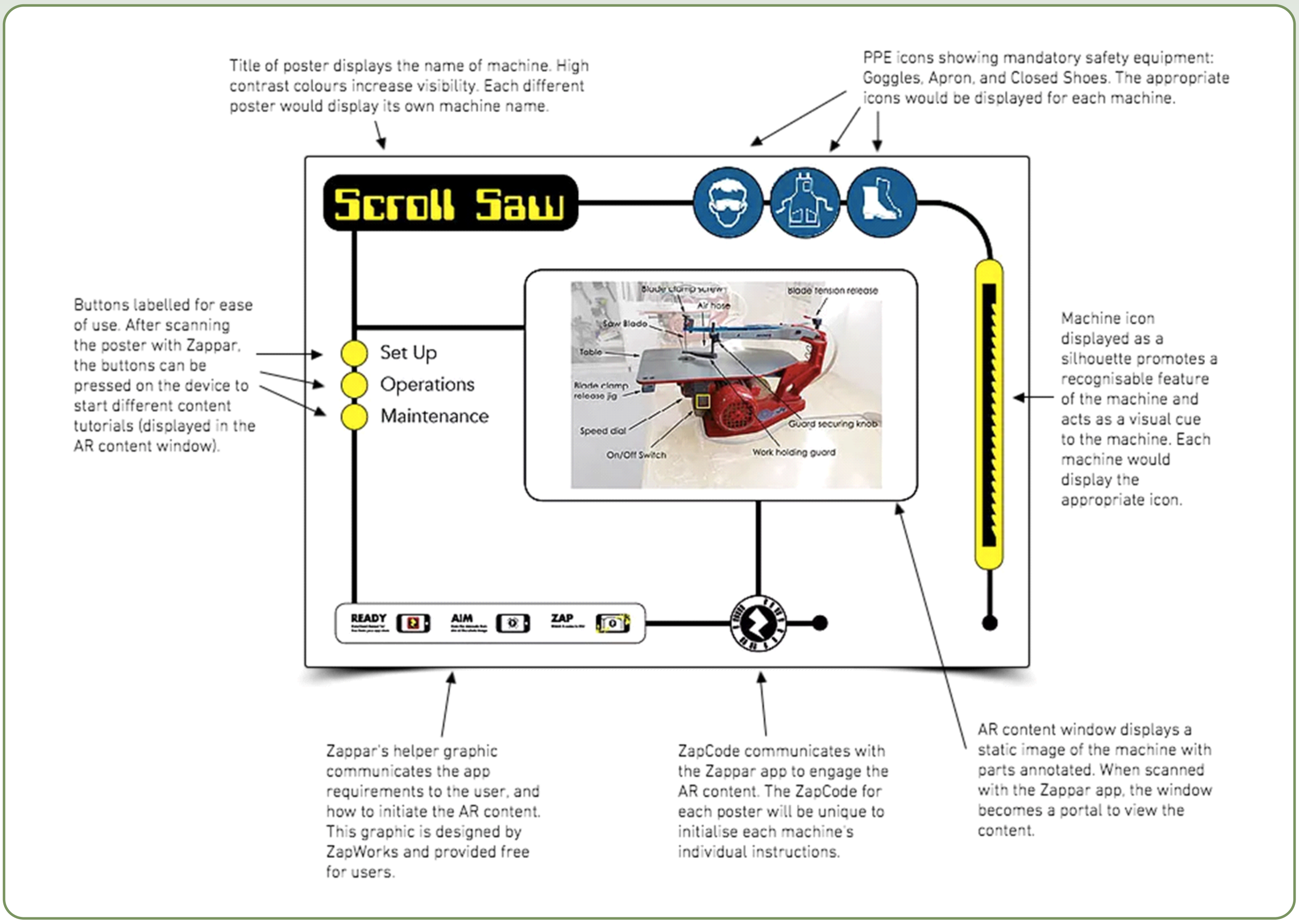
Black/Yellow Scheme 2: This modified version has a black Zapcode, increasing its functionality and this added black element is balanced by the modification of the icon element to yellow.

Final Design and Justification of Ideas

The final design is shown here, with annotations communicating an overview of design features and AR content.

Elements and Principles of Design

In design, the elements and principles assist designers in creating aesthetically pleasing and functional designs. The elements include Line, Shape, Colour, Texture, and Size. Graphic designers adhere to PARC (Proximity, Alignment, Repetition and Contrast) Principles to guide design decisions. Additionally, Balance and Space are principles adopted by many graphic designers ("The Principles of Design", 2016).



Elements

- Line
  - Lines have been used to create subtle connections. The border relates the title, across the top of the page, through the PPE icons and machine icon, highlighting safety aspects; similarly, the left line connects the operations with the AR content box, Zappar helper graphic and ZapCode.
- Shape
  - The circle shaped buttons were selected to mimic the PPE symbols and Zapcode (see Repetition below); furthermore, regular geometric shapes promote feelings of organisation and structure (Bradley, 2016) and are easily recognisable by learners as button shapes.
- Colour
  - A high-contrast, visually attracting aesthetic. Comparatively, it is the most visible, aiding in communicating the purpose of the poster, and ensuring prominence of important features (as required by established design criteria).
- Texture
  - A purposeful lack of texture limits distractions; McInerney (2014) suggests that sensory input will be hindered by poorly focussed attention.
- Size
  - The relative importance of elements has determined sizes. The large heading clearly identifies the poster topic. PPE symbols are a similar height to the heading, signifying their importance. The AR content window utilises the majority of the poster, for functionality. Similar elements are sized equally to create visual relationships.

Principles

- Proximity
  - Related features are located nearby each other, for example: the three PPE icons are grouped, as is the Zapper information and Zapcode, and the user buttons are located together, nearby the AR content box. This creates a visual relationship, reduces visual clutter and increases viewer comprehension ("The Principles of Design", 2016).

- Alignment
  - The PPE icons and buttons are aligned with each other in their groups, creating a visually predictable and cohesive poster. ("The Principles of Design", 2016). ZapWorks icons and ZapCode are closely aligned to ensure their association is clear to the user.
- Repetition
  - Repetition is used effectively through the circular motif, colours, and sizes of elements. The repeated circles assist in readability and comprehension (Schinkel, 2016); similarly, the yellow elements create a cohesive look that ties separate parts of the design together. Curved lines and borders further employ repetition to this end.
- Contrast
  - Contrast is mainly demonstrated by colour. The high contrast of yellow and black to the white background gives the user indications of what to focus on. The blue PPE symbols contrast to the rest of the design, creating a subtle chunk of information for learner encoding (McInerney, 2014).
- Balance
  - Balance refers to symmetry or asymmetry of elements in a design (Masters, 2016), and while my design is not symmetrical, it demonstrates asymmetrical balance in that the visual weight of elements is evenly distributed. This creates a pleasing aesthetic.
- Space
  - Positive and negative space have been used effectively. Elements are not too closely arranged, and allows for the separation of groups and individual elements ("The Principles of Design", 2016). This makes it easier for students to find information easily.

Managing Cognitive Load

When designing media-rich learning resources, consideration must be given to managing the cognitive load of the users to ensure that information gained is comprehended and retained. Greater levels of information increases strain on a student's mental resources, increasing cognitive load (Feinberg & Murphy, 2000) and consequently affect their ability to process content. Taking advantage of students' prior knowledge increases their ability to process the content provided by this resource, as schemas have been established and information is easily retrievable, reducing cognitive load (Valcke, 2002, as cited by Cook, 2006). Braune & Foshay (1983, as cited by Cook, 2006) suggest that interpretations of visual stimulus will be affected by prior knowledge. Students will have developed a prior understanding of the machine safety and operations and as such will have greater success interpreting the content on the poster.

Cook (2006) proposes instructional design considerations for managing cognitive load including dual-mode presentations, split-attention effect, redundancy, interactivity and instructional guidance.

Dual-Mode Presentations

Cook (2006) suggests that employing both visual and verbal stimulus has greater learning impact than using either independently and that greater quantities of information may be processed successfully this way.

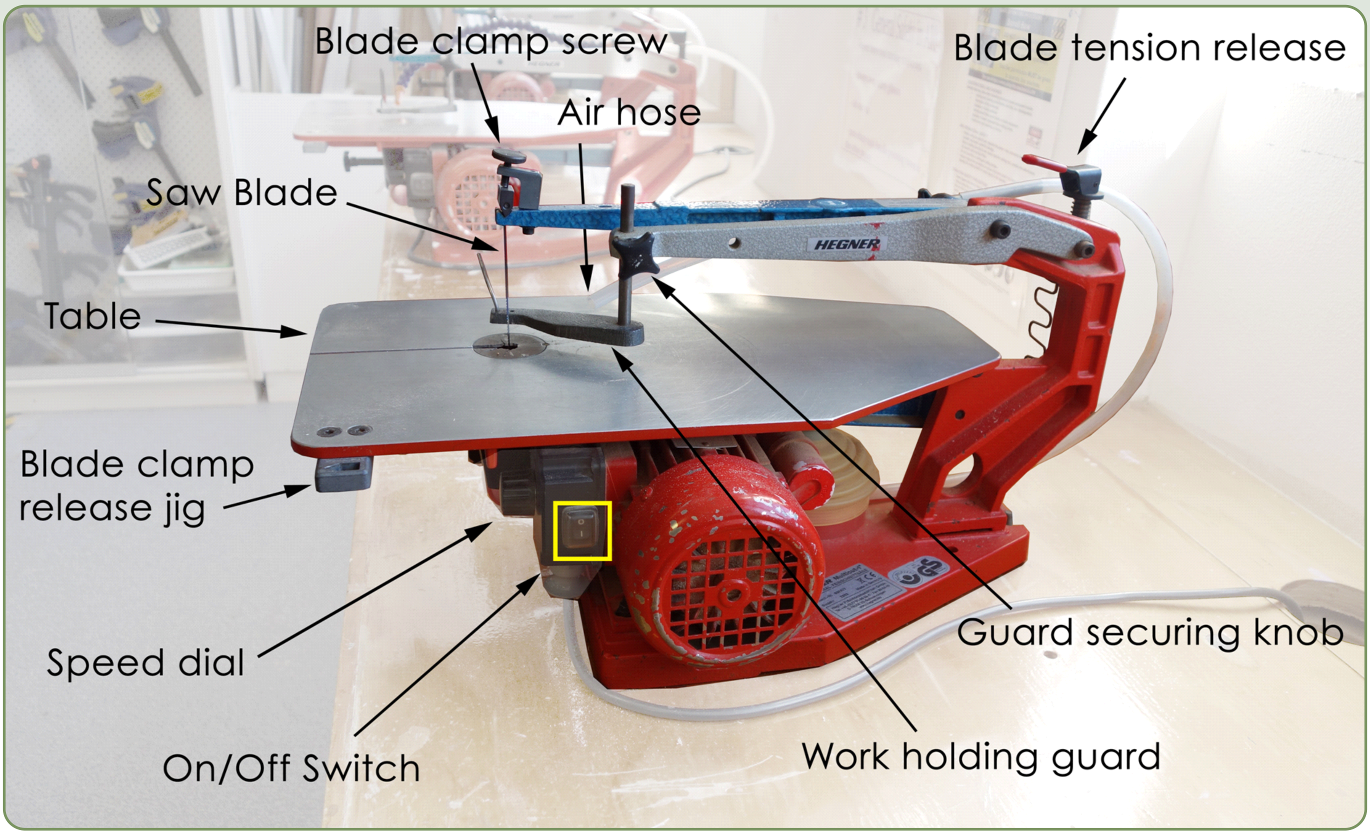
Paivio's dual coding theory concurs that these modes are processed independently in a learner's working memory (Paivio, 1986, as cited by Cook, 2006). Thus the decision was made to ensure that all videos included visual graphics, with a voice-over soundtrack. The introduction sequence of each video includes music, with on-screen text, another example of successful visual/auditory combination. All videos were produced consistently, demonstrating the application of dual-mode presentations.

Split-Attention Effects

Feinberg & Murphy (2000) assert that skill acquisition can be hindered through strain on working memory resulting from competition between text and graphics, however they do not clarify if text in this case is written or verbal. Cook (2006) suggests additionally that integration of complementary verbal text and graphics facilitates processing. Chandler and Sweller (1992, as cited by Cook, 2006) suggest that contiguous association of graphical and verbal information mitigates the cognitive load imposed by split-attention as learners can more easily form associations. Narration was used in my content videos to accompany the visual component to alleviate split-attention effects.

Redundancy

Redundant information creates cognitive load by requiring learners to process the same information twice (Cook, 2006). Despite the preference of teachers to have information repeated on the LMS (identified in Survey analysis), this would create redundancy of information, decreasing learning. Students transfer learning more successfully with narration accompanied visuals, than those with on-screen text (Mayer et al., 200, as cited by Cook, 2006). Feinberg & Murphy (2000) state that "Redundant sources of information place increased demand on cognition that can be freed for intrinsic load" (p. 3), suggesting maps as a fully featured graphic not requiring accompanying text. The labelled diagram of the scroll saw, shown below, similarly represents information that requires no



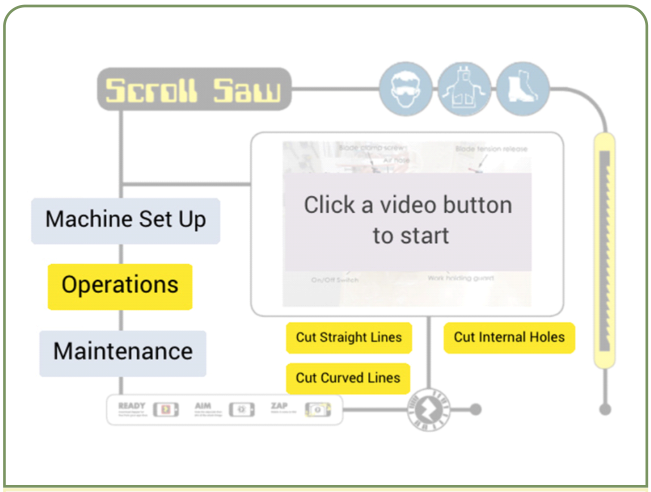
Interactivity

High levels of simultaneous interactivity places immense load on cognitive processing. Cook (2006) states that "if the number of interacting elements exceeds what can be processed by working memory simultaneously, it is unlikely that learning will occur" (p. 11), therefore, isolating interactive elements will enable learners to access the content more successfully. Functionally, it would not be possible to play multiple videos simultaneously.

Instructional Guidance

Students will need some level of guidance to contextualise learning from this resource. Cook (2006) suggests a balance of guidance to maintain quality of learning. The use of the Zappar helper graphic, shown below, on the poster provides guidance to students who have never used the app previously. As a new product in class, this was necessary for students to know how to access the app to view the AR content.

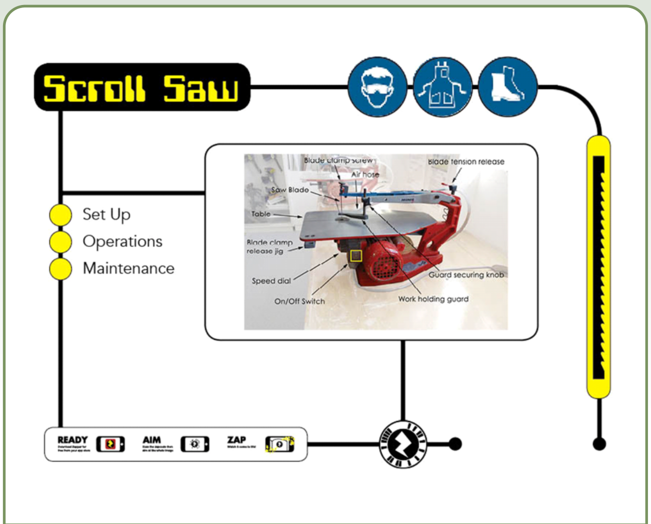
Further guidance is provided when the AR content is viewed, instructions are given on some screens to guide students to select a video to watch.



Zapworks designer view, showing instructional guidance buttons.

Evaluation

I evaluated the final product based on the success of the design and prototype, as well as commenting on the successful achievement of the design criteria set out previously.



Final Poster, To test the poster, please download and scan with the Zappar app.

Evaluation

Overall, I believed I had successfully met the objectives of the project. I set out to design and create an instructional resource that utilises augmented reality to reinforce the learning of safety and operations of machines in the Design and Technology Classroom.

Unexpected functionality provided by the ZapWorks Designer software enabled their "Grab n Go" feature, whereby once the AR content is initialised in the device, the student can move away from the poster to view the content. This allowed for added safety in the classroom, and multiple students could use the poster simultaneously.

Aesthetically, the software did not allow for ultimate design control and as such, some of the buttons did not appear as I had designed. The desired function still enables for effective engagement with the content despite the visual modifications.

Design Criteria Evaluation

Function:

- Effectively convey the required content using strategies like chunking, and scaffolding, as McInerney (2014) suggests, to provide more manageable pieces of information and build up levels of complexity
    - Chunking strategies were used effectively to manage content. Each video is less than 60 seconds in length providing manageable segments of information and aiding with information processing.
- Meaningful without added AR content so that students viewing the poster may increase their understanding of the machine prior to engaging with the AR content
    - The poster clearly conveyed static information on the parts of the scroll saw, useful information to aid students in better understanding this workshop tool.
- Use familiar terminology to activate prior knowledge, assisting in developing meaningful links between the student and content will increase learning potential (McInerney, 2014).
    - Throughout the videos, terminology was consistent and linked with terms on the static poster (eg parts of the machine). This developed product knowledge and helped students assimilate this learning effectively.
- Navigation structure should be consistent to promote ease of use. Predictable placement of features and elements across the posters will unify the collection, encouraging easier assimilation of knowledge.
    - Consistent navigation between "scenes" of AR content promoted easy use. ZapWorks Designer software was not as refined as preferred and consequently the final layout differed slightly from design, however, still consistent.
- Manage cognitive load by providing multi-modal forms of instruction, but limiting competition between too many elements to avoid information processing failure.
    - Cognitive load was managed effectively through content design. All videos demonstrate contiguous integration of verbal and visual elements, enabling successful processing by the learners.

Aesthetics:

- Prominence of features like buttons will ensure ease of use as these features will be correctly interpreted by the student (McInerney, 2014).
    - Colour choice of buttons and other elements aids the interpretation of their function.
- Use familiar symbols to activate prior knowledge, similar to terminology above. An example might include standard PPE symbols as determined by the International Organization for Standardization (ISO) as these symbols are recognised worldwide.
    - Familiar symbols and terms are used throughout to create a cohesive and easily accessed product.
- Design the content using the elements and principles of design and PARC principles will help create an aesthetically pleasing product.
    - As justified previously, the elements and principles of design have been successfully used in the design of the product. The final prototype did not match the design as preferred. This was a result of the limitations of the software. With more time, more sophisticated software could be used to create a preferred look.

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Digital Learning and
Teaching Victoria
61 Blyth Street
Brunswick VIC 3056 Australia

Phone: +61 3 9349 3733

Email: office@dltv.vic.edu.au
www.dltv.vic.edu.au

Digital Learning
and Teaching Victoria