Creative digital technology ideas for the secondary school mathematics classroom

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This article describes open-ended activities using digital technologies in secondary school mathematics classrooms that encourage novel investigation of science, technology, engineering and mathematics (STEM) concepts.

Introduction

Crucial for Australia's future economic prosperity is to bridge the innovation divide between 20th and 21st century technological skills. To encourage creativity, schools need to implement practical teaching strategies involving digital technology devices. Creativity is often erroneously considered the domain of artists, but the creation of novel, valuable processes and products in the 21st century is, in fact, underpinned and scaffolded by mathematical prowess. Commonly, ubiquitous digital technology devices are used as socialising and gaming accoutrements for trivial purposes and not for creativity. As such, they can be sadly underutilised as tools for promoting and communicating higher-order thinking, particularly by adolescents.

In recent decades in Australia, there has been a trend of declining enrolments of both genders into STEM subjects, jeopardising Australia's future human capital and economic prosperity (Kennedy, Lyons and Quinn, 2014). This downward trend can be reversed at the grass roots level by engaging students with real-life applications of mathematics through digital technology. To do so, a school requires a critical mass of enthusiastic staff with high expectations to create the self-fulfilling prophecy of a positive attitude towards, and ability in, mathematics, along with a commitment to embed meaningful digital technology activities into the curriculum of secondary school students.

Creativity and digital technologies struggle to find their place within the mathematics curriculum. The mathematics classroom has a reputation as the location for doing sums and solving problems, however, it is in the solving of these problems that creativity and technology can flourish. Creativity is an essential skill in solving any problem and with technology development being an important factor in the 21st century, it is vital that students learn to solve problems that utilise technological tools.

Perceptions and misconceptions of creativity in mathematics

Creativity is beneficial for problem solving as solutions are frequently found by thinking in an abstract, creative manner. The following perceptions of creativity are important to mathematics teachers as mathematics is a keystone of the STEM disciplines.

Firstly, there is a public perception that creativity is lacking in STEM subjects (Schmidt, 2011) and is more likely to be associated with visual and performing arts (Harlow, Nylund-Gibson, Iveland & Taylor, 2013). Contrary to this view, artists are dependent on many STEM experts: chemists to develop improved paint and sculptural media; physicists to invent innovative lighting devices; and information technologists to prepare software to broadcast images. This misconception of a creativity deficit in mathematics was reported in studies that showed that a majority of mathematically talented students relied heavily on technical algorithms with only a basic level of creativity in problem-solving challenges (Aizikovitsh-Udi, 2014) and that less academically gifted students scored higher in creativity (Blake, McCarthy and Krause, 2014). Arguably, this reliance on algorithms may be the consequence of the recent Australian trend towards Hobbesian-style tests such as National Assessment Program—Literacy and Numeracy (NAPLAN). To run concurrently with this trend, more open-ended tasks would prove beneficial to engage teenagers in mathematics.

Secondly, for some years, there has been a reduced interest level in mathematics by middle years girls (OECD, 2009). However, research evidence showed that girls and boys achieved equivalent test scores in problem solving, with girls out performing boys in identifying key components of investigative research and in reading (Organisation of Economic Cooperation and Development, 2009) with no disparity between print-and computer-based texts (Higgins, Russell and Hoffmann, 2005). In his comparative gender research, Schmader (2002) attributed the observed decline by females in his problem-solving tasks to intrusive negative thoughts of the females with subsequent limitation of available working memory capacity, and not to any intellectual incapacity.

Thirdly, in a Finnish study, Vedenpaa and Lonka (2014) found that teachers viewed creativity as a changeable construct and not as an innate, inert entity, particularly when collaboration between learners was facilitated. The latter view bodes well for positive intervention by enthusiastic staff at the school level to change the mindsets of disengaged students. Therefore, it could be argued that the declining trend of interest in mathematics could be easily reversed if creativity is cultivated in a rich digital technology environment.

Elements of environments that enable creativity and problem solving

Play and art, derived from lived experiences, are indispensable pre-requisites for 'thinking outside the box', an essential cognitive quality of innovative mathematicians, scientists and engineers. In a Taiwanese study, Chang (2013) espoused that personal playfulness was a significant predictor and enhancer of creative ability. Art was also found to be intrinsically motivating, in turn, germinating curiosity and expanding multi-faceted visual and geometric perspective parameters (Piske, Stoltz and Machado, 2014).

In an optimistic environment that is both playful and serious, there is a social element to problem-solving that predominantly involves collaboration, but also the competitiveness between gifted individuals. According to Vygotsky (1994), children should be presented with challenging tasks that are slightly more advanced than their current abilities and that cause an uneasy disequilibrium to ignite curiosity. For the students' attained knowledge and skills to be transferable to their own real-life settings in this fast-evolving 21st century, it would be prudent to have teams comprising both students and teacher guides in secondary school mathematics classrooms.

However, not all team work is conducive to creative outcomes; an effective working team has a common goal, a visionary leader and collaborating individuals with a diverse range of knowledge and skills (Pisanu and Menapace, 2014). The leader, that is, a teacher in a classroom, may exert indirect influence through role-modelling of critical thinking to separate facts from opinions (Facione, 2011). Further, teachers need to highlight the aesthetic aspect of problem solving by celebrating the incremental achievements of individuals and the group.

A crucial consideration is the provision of sufficient time for students to intentionally pursue their creative endeavours (Hadzigeorgiou, Fokialis and Kabouropoulou, 2012). Time is required at various points along the creative, sometimes rambling, journey in an adolescent's mind when s/he first conceives and then incubates a problem, dismisses irrelevant notions, and then pursues a more crystallised, illuminated thought process towards an end goal. To mitigate the time constraints of the classroom curriculum, access to digital technology devices and teacher guides in extra-curricular *Makerspaces* is recommended. Ultimately, the success of implementing creative mathematics problem-solving environments to provide opportunities for play and collaboration is significantly defined by the form of school leadership, existing school logistics and availability of funds.

School leadership, funding and accountability

Exhortative school leadership drives the success of student outcomes in secondary school mathematics by providing opportunities to access resources and professional development. As such, funds to purchase digital technology devices and to up-skill are required. As digital technology devices and professional development providers are often expensive, funding from both the school hierarchy and external sources may be required. Numerous grants are available from gaming machine organisations and IT corporations.

Running parallel with such funding is the requirement of staff to show accountability in terms of improved student outcomes. These outcomes can be measurable through improved student academic results in higher level mathematics courses, increased student numbers in digital technology workshops, and the expanding diversity of student-designed technology products and processes. Without assistance from a school administration to enable projects, staff resistance may be encountered, leading to an osmotic negative perspective in students.

Specific targeting of marginalised students for optimal positive impact

To attain the most effective use of digital technologies, specific student groups need to be targeted. Whether the project is a formative classroom activity or an assessable assignment, the topic, design and logistics of activities should consider the targeted audience, particularly with regard to gender and cultural background. Imperative is a sense of belonging with like-minded peers (Pelletier and Sharp, 2008) and custom tailoring of activities to suit personality types (Hirsch, Kang and Bodenhauser, 2012).

At the start of any mathematics project involving digital technology, it is recommended for girls to work in their own groups to improve confidence and skills, and have their accomplishments celebrated with photographs published in school newsletters and local newspapers. To further enhance the feminised STEM image, inspirational mentoring professionals from industry and academia, such as the free, in-school *Robogals* from the University of Queensland, are advantageous to provide a human connection.

Activities can also be readily tailored for other cultural groups. Indigenous youth can analyse movement with kinetic body movement nodes in sport and dance. In rural areas, pragmatically-minded students can use UAVs (drones) to do aerial photography for surveying, perimeter, area, speed and animal density calculations. To track and celebrate their achievements in this plethora of digital technology skills, mathematics students may compile video-diaries or developmental e-portfolios under teacher supervision.

Digital technology ideas for the mathematics classroom

Table 1 lists digital technology ideas that have been successfully embedded into the authors' school's Years 7 to 10 *Australian Curriculum: Mathematics* (Australian Curriculum, Assessment and Reporting Authority, 2012) as teaching and learning activities and open-ended problem-solving assessment. Noteworthy is the *Lego EV3* robot as it is cost-effective due to its multiplicity of applications. Many other devices may already be available within the school and the local community, but need merely to be more creatively utilised for mathematics activities.

Conclusion

With the increase in the requirement for digital technology skills and creative problem solving in the professional world, it is important that these skills are taught to our secondary school mathematics students. As educators, it is up to us to overcome barriers of misconceptions, limited funding, time constraints, and insufficient skill levels to provide opportunities for students to access, learn and cultivate their creative skills. By enabling these abilities to mature, we are providing our students with a better capacity to apply creatively the knowledge learnt at school and to make it applicable to the myriad of innovative careers in their future.

Table 1: Digital technology ideas that have been successfully embedded into the school's Years 7 to 10 mathematics curriculum.

	Number and Algebra	Measurement and Geometry	Statistics and Probability
Year 7	• **Lego EV3 robot** Positive and negative integers through forward and backward movement • **Lego EV3 robot** Addition of fractions by adding half-turns and quarter-turns, multiplication of half of half • **Lego EV3 robot** Distance-time linear graphs • **Fitness tracker** Comparison rates of the week's exercises • **Solar panel monitoring device** Energy usage rates in different buildings • **Safari park webcam** Animal population density • **Excel** Currency exchange spreadsheet • Many free and commercial online **arithmetic mastery programmes**	• **Dot matrix LED panel** Time periods in milliseconds • **Google Maps** Distances and speed • **Virtual tour of art gallery** Painting exhibition areas • **Kinetic body movement nodes** Angles for biomechanics and film animation	• **Codebug** Probability with dice • **Survey monkey** Questionnaire • **Temperature sensor and data storage** Time graphs

	Number and Algebra	Measurement and Geometry	Statistics and Probability
Year 8	• **Lego EV3 robot** Gear ratio and speed • **Smartphone** Filming car for speed calculation • **Codebug** Cartesian coordinates with animated sprites • **Lux meter** Light intensity percentages to identify optimal solar panel placement	• **Lego EV3 robot** Investigate pi from circumference and diameter measurements • **Distometer** Length measurement • **Excel** Landscaping cost spreadsheet with length conversion, perimeter, area, volume • **Computer graphics** 2D and 3D package design • **Lego EV3 robot** Draw angles and 2D shapes; rotate and translate drawn 2D shapes • **Photoshop** Image transformations • **Codebug** Transformation with animated sprites	• **Online gaming machine simulators** and **random number generator** Multi-step probability • **Codebug with infrared motion sensors** Count student movement in different school walkways followed by statistical analysis to identify congestion areas
Year 9	• **Smartphone app. with VU (Volume Unit) meter** Measure decibels of drum beats (index notation) • **Digital microscope** Scientific notation • **Adafruit wearable technology with neo-pixels and accelerometer** Index notation, algebraic substitution, time periods in milliseconds • **Multimeter** Total resistance of series and parallel electric circuits	• **Lego EV3 robot on a slope** Pythagoras' theorem, gradient, trigonometry • **Pressure sensor** Determine if a glass is half full	• **Excel** Measures of central tendency of Australian Bureau of Statistics demographics data
Year 10	• **Fitness tracker GPS** Terrain contours and cross-sections as non-linear graphs • **Smartphone** Filming of projectile trajectory • **Excel** Equation of motion-captured trajectory image • **Lux meter** Inverse square law of light and distance	• **Lego EV3 robot maze, Lego EV3 robotic arm** Cartesian coordinates, angles, Pythagoras' theorem and trigonometry • **UAV (drone)** Orienteering, compass bearings, distances, area • **Distometer** Speed, acceleration • **Theodolite** Horizontal and vertical angles and trigonometry • **3D printer, 3D pen, CNC milling machine** 2D perspectives, volume of irregular solid	• **Online research** Median house prices • **Online "Islands in Schools Project"** Statistical investigations

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