australasian journal of
TECHNOLOGY EDUCATION

The Australasian Journal of TechnologyEducation is a peer refereed journal, and provides a forum for scholarly discussion on topics relating to technology education. Submissions are welcomed relating to the primary, secondary and higher education sectors, initial teacher education and continuous professional development, and general research about Technology Education. Contributions to the on-going research debate are encouraged from any country. The expectation is that the Journal will publish articles at the leading edge of development of the subject area.
The Journal seeks to publish

- reports of research,
- articles based on action research by practitioners,
- literature reviews, and
- book reviews.

Publisher: The Technology, Environmental, Mathematics and Science (TEMS) Education Research Centre, which is part of the Faculty of Education, The University of Waikato, publishes the journal.

Contact details: The Editor, AJTE, pjohn.williams@curtin.edu.au

Cover Design: Roger Joyce

ISSN: 2382-2007

australasian journal of
TECHNOLOGY EDUCATION

Initial teacher education students' conceptions of creativity in technology and science education: A large-scale New Zealand study

Matthew Courtney
Kerry Lee
Anne McGlashan
Meripa Toso
Paul Neveldsen

Abstract

Teacher misconceptions about the nature and intent of Technology education (henceforth, Technology) in school sectors is of concern. Research suggests that elementary teachers too often do not have a basic grasp of the central tenets associated with Technology and how it differs from Science. Research by Atkinson (2000) has found that teacher educators too often design Technology lessons with a linear problem solving approach, leaving little opportunity for student creativity and imagination. Using a large sample of Initial Teacher Education (ITE) students (N = 830) this study found that early childhood education ITEs were less inclined to agree with the notion that Technology was mostly about creativity, design, and showing others your ideas. In addition, students thought that creativity was more applicable to Technology (as opposed to Science), although older male students thought that creativity was more relevant to both subjects. Implications for policy and practice are discussed.

Key Words: Technology Education, Primary and Early childhood education, Quantitative, Teacher Learning and Development, Instructional Design/Design Principles.

Introduction

This paper briefly outlines why teachers' understanding of the main premise of Technology and why their conceptions of creativity in Technology and Science are important to teacher educators, training and practicing teachers, and early childhood education (ECE) and primary students. The paper also provides a rationale for gauging ITE student's conceptions upon entry, and assessing the role of student teacher experience, demographic, sector, and degree-level variables on such conceptions.

Literature Review

On the (mis)conceptions of technology and science

Technology (sometimes referred to as Design, or Design Technology) has been through many changes over the years. Focus has shifted from technical and life skills, to vocational and industrial arts, through to its many current international forms (Ferguson, 2009; Granshaw, 2015; Jones, Buntting, & de Vries, 2013; Martin & Ritz, 2012). Unfortunately, these multiple iterations have led to confusion about the nature and intent of the subject (Medway, 1989). One of the more common misconceptions is that associated with the understanding of the central tenets of Technology and how they differ from Science (Constantinou, Hadjilouca, & Papadouris, 2010; Williams, 2011). Gregory (1966) helps provide clear distinction between the methods employed in the two subjects: "the design [Technology] method is a pattern of behaviour employed in inventing things… which do not yet exist;" whereas, "The scientific method is a pattern of problem-solving behaviour employed in finding out the nature of what exists" (pp. 323-330). Thus, Technology is design centred and constructive, whereas Science is analytic. A sound understanding of Technology and its distinction enables the establishment of clear goals, classroom activities and authentic contexts (Brown & Brown, 2010) which leads to the development of technological literacy (Lewis, 1995; Skophammer & Reed, 2014), the ability to appropriately select and responsibly use technology. Much of the recent research in New Zealand also supports this notion. For example, Almutairi, Everatt, Snape, and Fox-Turnbull (2014) provide clear criteria to assist educators to distinguish between the two disciplines as a useful pedagogical tool.

Creativity and student learning

Schmidt (2011) found that students and teachers often identify rote learning and rigid dogmatic thinking as characteristics essential for success in Science (Barak & Shachar, 2008; Barton, Tan, & Rivet, 2008). The New Zealand Education Review Office (ERO) (2012) found that only a little over a quarter of primary and intermediate schools have effective science programs, and by Year 8 (when students are 11-13 years old) few students see themselves in STEM-based careers (Crooks, Smith, & Flockton, 2007). In the majority of the 100 schools surveyed where Science learning was deemed ineffective, students experienced knowledge-based programs rather than interactive, investigative approaches that provide opportunity for student creativity and imagination (Crooks, Smith, & Flockton). To understand the lack of creative opportunity in the classroom, it is important first to define creativity in the context of STEM learning, and then to explore how teachers might consider the applicability of creativity across disciplines.

Seltzer and Bentley (1999) provide the following useful definition for educational contexts: "Creativity is the application of knowledge and skills in new ways to achieve a valued goal" (p. 10). Throughout technological and scientific processes, creativity is often identified by the so-called 'creative leap' (Dorst & Cross, 2001). Besides being critical to education and learning, creativity is an integral part of everyday life and twenty-first century living (Craft, 2005; McWilliam & Haukka, 2008; Piffer, 2012). Thus, creativity is of obvious importance to practical curriculum areas such as Technology (Fox-Turnbull, 2010; Pavlova, 2005) and Science (DeHaan, 2009; Longshaw, 2009). Research suggests that affording creative opportunities in Science, Technology, Engineering, and Mathematics (STEM subjects), alongside a degree of intentional structure, can support deep student learning (Blikstein, 2013; Vossoughi, Escudé, Kong, & Hooper, 2013).

Initial teacher conceptions of creativity

Over the last three decades, New Zealand's Technology and Science curricula have undergone numerous changes. Broadly, design and creativity has played key roles in each iteration (Ferguson, 2009; Ministry of Education, 1993, 1995, 2007). It is evident, no more so than the first line of the national curriculum where it is stated that "Technology is intervention by design" (Ministry of Education, 2007, p. 32). New Zealand's Science curriculum (Ministry of Education, 2014) also sees creativity as essential, stating that "scientific progress comes from logical, systematic work and from creative insight" (p. 1).

For this reason, teachers need to have a sound understanding of what creativity is and how to create an environment which will foster creativity in Technology and Science—this includes carefully managing time, the physical and pedagogical environment (Addison, Burgess, Steers, & Trowell, 2010) and developing relationships (Gandini, Hill, Cadwell, & Schwall, 2005). Teacher educators have a key role in developing this understanding whilst student teachers are undertaking their initial teacher education (Koster, Brekelmans, Korthagen, & Wubbels, 2005). Just as a teacher needs to know their students' starting point before teaching, so too a teacher educator needs to understand student teachers' initial understanding and values (Schneider, Pakzad, & Schlüter, 2013). Little is known about ITE student conceptions on entry. What are their views on the fundamental tenants underlying Technology? Do ITE students understand that Design is a process that can turn ideas into products, and, that Technology is about creativity, design, and showing others your ideas? Do they see student creativity as being relevant to Technology and Science? Which cohorts, upon entry, might bring with them misconceptions about Technology and Science? Do undergraduates have the same views as graduate students?

There are many influences on people's initial beliefs and understanding of curriculum subjects. These include prior experience (Schneider et al., 2013), academic and educational backgrounds (Goldman, Yavetz, & Pe'er, 2014), age, gender and ethnicity (Lin, Tsai, Chai, & Lee, 2013). This study uses a single level regression model to assess the effect of student teacher demographic, high-school experience, sector-of-study, and degree-level on ITE student conceptions of design and creativity within Technology. To achieve this, three research questions, each with two parts, were posed.

RQ1a: Do ITE students believe that *Design is a process that can turn ideas into products?*

RQ1b: What effect does experience and demographic have on this perception?

RQ2a: Do ITE students believe that *Technology is most about creativity, design, and showing others your ideas?*

RQ2b: What effect does experience and demographic have on this perception?

RQ3a: Do ITE students believe that Creativity is relevant to both Science and Technology?

RQ3b: What effect does experience and demographic have on this perception?

Methodology

Quantitative survey methods, descriptive statistics, and single-level modelling were used to study the effects of ITE student demographic, high-school experience, sector-of-study, and degree-level on entering student teachers' understanding of Technology, and their views on the relevance of creativity to Technology and Science. After obtaining ethical approval, and completing a successful pilot study in July 2013, student teachers entering the 2014 (March) and 2015 (March) teacher education programs were invited to participate in the research. Therefore, convenience sampling constituting several waves of data were utilised. Student teachers participating in the survey included those enrolled in the mainstream three-year bachelor of education (B.Ed.) primary; the mainstream three-year B.Ed. ECE; the Pasifika (specialising in learning for Pacific Island peoples) B.Ed. ECE; the graduate diploma ECE; and graduate diploma primary programs.

Participants

In total, 830 participants studying in New Zealand were involved in this study. As illustrated in Table 1, the majority (83.6%) of the participants were female and most participants (65.7%) were aged between 17 and 24 years old (see Table 1).

Table 1: Proportion of male and female participants for each age group

Age Group	Gender				Total	
	Male		Female			
	n	%	*n*	%	*n*	%
Categorised by Four Age Groups						
17-24	73	8.8	472	89.1	545	65.7
25-30	31	3.7	86	10.4	117	14.2
31-36	8	1.0	52	6.3	60	7.7
37+	24	2.9	84	10.1	108	13.0
Categorised by Two Age Groups						
17-24	73	8.8	472	89.1	545	65.7
25+	63	7.6	222	26.7	285	34.3
Total	136	16.4	694	83.6	830	100

Note. Percentage values pertain to percent of total 830 valid responses; percentages rounded to one decimal point so columns may not tally.

The participants are categorised by gender, degree-track, and sector. The majority of the student teachers (*n* = 429, 51.7%) were part of the undergraduate primary school program. The majority of the participants were female (*n* = 694, 84.5%). Two thirds (*n* = 554) of the students were studying toward undergraduate degrees; a third (*n* = 267) toward graduate degrees (see Table 2).

Table 2: Proportion of male and female participants for each sector and degree-track

Sector	Gender				Total	
	Male		Female			
	n	%	*n*	%	*n*	%
Undergraduate Degrees						
ECE (Pasifika)	2	0.2	25	3.0	27	3.3
ECE	2	0.2	96	11.6	98	11.8
Primary	75	9.0	354	42.7	429	51.7
Undergraduate Total	79	9.5	475	57.2	554	66.7
Graduate Diplomas						
ECE	2	0.2	52	6.3	54	6.5
Primary	55	6.6	167	20.1	222	26.7
Graduate Total	57	6.9	219	26.4	267	33.3

Note. Percentage values pertain to percent of total 830 valid responses; percentages rounded to one decimal point so columns may not tally.

Instruments

With reference to New Zealand's Technology curricular framework (Forret et al., 2013), the instrument used in this investigation was jointly developed by New Zealand's six information technology education (ITE) providers[1] to assess ITEs' base understanding of Technology and the role of creativity. RQ1a elicits degrees of agreement with the following statement: *Design is a process that can be used to turn ideas into products* (response options are 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). For RQ2, the following statement is presented: *Technology is most about creativity, design, and showing others your ideas* (response options are 1 = No/Marginal focus, 2 = Some Focus, 3 = Heavy focus). For RQ3, participants are asked whether they think creativity is relevant to Technology (coded 1), both Technology and Science (coded 2), or Science (coded 3).

Data Preparation and Analysis

Data was screened, cleaned and assessed for normality (skewness and kurtosis under |1.0| and |2.0|, respectively) prior to missing value analysis which revealed that data was missing in a systematic way (Little, 1988) (MCAR test: $\chi^2 = 1645.218$, $df = 1507$, $p = .007$), therefore, imputations were not defensible and there was some variation in sample size for each question. A single level regression model (MLWin 2.31, 2015) was used in the current study as it provides a simple way to model the effect of reference-associated variables on outcomes of interest (Rabash, Steele, Browne, & Goldstein, 2012). (Note, a multilevel model was not possible due to only five sampled groups participating in the study). Age was modelled as a

[1] Auckland, Canterbury, Massey, Otago, Victoria, and Waikato universities.

nominal variable whereby the youngest age group—17- to 24-years—was identified as the reference. This was done to identify specific groups that may differ in terms of their understanding of Technology and conceptions of creativity. The gender variable was modelled with female as the reference group. The variable concerned with students' prior attainment of National Certificate of Educational Achievement (NCEA) high school Technology credits was modelled *no credits attained* as the reference. This was done to examine the effect of relevant prior experience on the outcomes of interest. The effect of the cohort groupings was assessed with the undergraduate primary cohort (the largest cohort subsample) as the reference group. Note that, normality plots on residuals at level 1 appeared linear suggesting that the assumption of normality was met (Rabash et al., pp. 43-44). In accordance with Rabash et al., IGLS estimation was used. Where reference groupings were modelled, an assessment of the standardized size of the difference in comparison groups (Cohen's *d*) is made in accordance with the following conventions: small, $0.20 \leq d < 0.40$; medium, $0.40 \leq d < 0.60$; and large $0.60 \leq d$ (Hattie, 2009).

Findings

ITEs' beliefs about relationship between design and products

To answer RQ1a, descriptive statistics were generated. On average, students tended to agree at a moderate to high level with the notion, *Design is a process that can turn ideas into products* (M = 4.20, SD = 0.79, N = 830; note, agree = 4, strongly agree = 5). For RQ1b, results of the model (see Table 3) suggested that the general high level of agreement was consistent across all demographic, experiential factors, and degree-track groups.

Table 3: Demographic predictors of agreement with *Design is a process that can be used to turn ideas into products*

Parameter	Model 1 unconditional	Model 2 demographics	Model 3 NCEA exp.	Final Model Degree-sector
		Fixed effects		
Intercept	4.21 (0.03)	4.07 (0.07)	4.03 (0.08)	4.03 (0.08)
Level 1				
Age Group (ref: 17–24)				
25–30		0.03^{ns} (0.08)	0.05^{ns} (0.08)	0.08^{ns} (0.08)
31–36		0.08^{ns} (0.11)	0.11^{ns} (0.11)	0.13^{ns} (0.11)
37+		0.07^{ns} (0.08)	0.11^{ns} (0.09)	0.13^{ns} (0.09)
Male (ref: female)		-0.14^{ns} (0.07)	-0.10^{ns} (0.06)	-0.11^{ns} (0.08)
NCEA Credits (ref: no credits)			0.10^{ns} (0.06)	0.11^{ns} (0.06)

Level 2 (ref: B.Ed Prim., mainstr.)				
Undergraduate Degrees				
ECE (mainstream)				0.15^{ns} (0.09)
ECE (Pasifika)				0.05^{ns} (0.16)
Graduate Diplomas				
ECE (mainstream)				0.05^{ns} (0.12)
Primary (mainstream)				-0.05^{ns} (0.07)
Random Effects				
Between cohort variance (σ^2_{u0})	0.000 (0.000)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Change in cohort variance ($\Delta\sigma^2_{u0}$)		0.00	0.00	0.00
Student variance (σ^2_e)	0.621 (0.030)	0.62 (0.03)	0.62 (0.03)	0.61 (0.03)
-2*log likelihood	1959.60	1955.27	1952.61	1948.39
Change in -2*log likelihood		-4.33^{ns}	-2.66^{ns}	-4.22^{ns}

Note. N = 830, M = 4.20, SD = 0.79; response options range from 1 = strongly disagree, to 5 = strongly agree; Level 1 and Level 2 values pertain to unstandardized beta values (β); unstandardized errors are in parentheses; NCEA exp. = National Certificate for Educational Achievement experience; ^{ns} = not statistically significant, $*p < .05$, $**p < .01$, $***p < .001$; changes in degrees of freedom taken into account when estimating significance of change in -2*log likelihood; (estimations calculated to 3 decimal places, final rounding to 2).

ITEs' Conception of Central Tenets of Technology

To answer the second research question (RQ2a), descriptive statistics suggested that, on average, student teachers tended to believe that Technology had a heavy focus on creativity, design, and showing others your ideas (M = 2.62, SD = 0.53, N = 830; note, 2 = some focus, 3 = heavy focus). For RQ2b, results of the model (see Table 4) suggested that this level of agreement was largely stable for the individual and group factors; however, in the final model, compared with the mainstream B.Ed. primary school cohort, the graduate diploma ECE group (unstandardized β = -0.16, p < .05; Cohen's d = -0.30, small) tended to think that technology was not quite as heavily focused on creativity, design, and showing others your ideas.

Table 4: Demographic predictors of perceived agreement with *Technology the subject is most about creativity, design, and showing others your ideas*

Parameter	Model 1 unconditional	Model 2 demographics	Model 3 NCEA exp.	Final Model Degree-sector
		Fixed effects		
Intercept	2.62 (0.02)	2.62 (0.02)	2.59 (0.03)	2.61 (0.03)
Level 1				
Age Group (ref: 17 - 24)				
25–30		0.03^{ns} (0.06)	0.04^{ns} (0.06)	0.07^{ns} (0.06)
31–36		0.02^{ns} (0.07)	0.04^{ns} (0.07)	0.08^{ns} (0.08)
37+		0.00^{ns} (0.06)	0.02^{ns} (0.06)	0.06^{ns} (0.06)
Male (ref: female)		-0.06^{ns} (0.05)	-0.06^{ns} (0.05)	-0.06^{ns} (0.05)
NCEA Credits (ref: no credits)			0.08^{ns} (0.04)	0.08^{ns} (0.04)
Level 2 (ref: B.Ed Primary, mainstr.)				
Undergraduate Degrees				
ECE (mainstream)				0.00^{ns} (0.06)
ECE (Pasifika)				-0.06^{ns} (0.11)
Graduate Diplomas				
ECE (mainstream)				-0.16* (0.08)
Primary (mainstream)				-0.07 (0.05)
		Random Effects		
Student variance (σ_e^2)	0.29 (0.01)	0.29 (0.01)	0.28 (0.01)	0.28 (0.01)
-2*log likelihood	1296.57	1295.10	1291.70	1286.13
Change in -2*log likelihood		-1.46^{ns}	-3.41^{ns}	-5.57^{ns}

Note. N = 818, M = 2.61, SD = 0.54; response options range from 1 = No/Marginal focus, to 3 = Heavy focus; Level 1 and Level 2 values pertain to unstandardized beta values (β); unstandardized errors are in parentheses; uncond. = unconditional, demo. = demographic factors, NCEA exp. = National Certificate for Educational Achievement experience; ^{ns} = not statistically significant, *p < .05, **p < .01, ***p < .001; changes in degrees of freedom taken into account when estimating significance of change in -2*log likelihood; (estimations calculated to 3 decimal places, final rounding to 2).

ITEs' Perception of applicability of creativity to technology and science

For the third research question (RQ3a), simple descriptive statistics revealed that, on average, students believed that creativity was more applicable to Technology (M = 1.51, SD = 0.56, N = 830; note Technology = 1, both = 2, Science = 3). For RQ3b, results suggested that this tendency was stable with respect to NCEA experience with Technology, and degree-track groupings (see Table 5). However, compared to the younger reference age-group of 17 to 24 year-olds, the 37-plus age-group (β = .21, p < .001, Cohen's d = 0.38, small) was more inclined to see creativity as part of Science as well; and the males (β = .15, p < .01, Cohen's d = 0.27, small) were also more inclined to view creativity as part of both disciplines.

Table 5: Demographic predictors of the perceived applicability of 'creativity' to technology, both science and technology, and science

Parameter	Model 1 unconditional	Model 2 demographics	Model 3 NCEA exp.	Final Model Degree-sector
		Fixed effects		
Intercept	1.51 (0.02)	1.44 (0.03)	1.44 (0.03)	1.42 (0.03)
Level 1				
Age Group (ref: 17–24)				
25–30		0.04^{ns} (0.06)	0.04^{ns} (0.06)	0.03^{ns} (0.06)
31–36		0.12^{ns} (0.08)	0.12^{ns} (0.08)	0.11^{ns} (0.08)
37+		0.23*** (0.06)	0.23*** (0.06)	0.21*** (0.06)
Male (ref: female)		0.14** (0.05)	0.14** (0.05)	0.15** (0.05)
NCEA Credits (ref: no credits)			0.01^{ns} (0.05)	0.02^{ns} (0.05)
Level 2 (ref: B.Ed Prim., mainstr.)				
Undergraduate Degrees				
ECE (mainstream)				0.03^{ns} (0.06)
ECE (Pasifika)				0.17^{ns} (0.11)
Graduate Diplomas				
ECE				0.12^{ns} (0.08)

(mainstream)				
Primary (mainstream)				0.03^{ns} (0.05)
		Random Effects		
Student variance (σ_e^2)	0.31 (0.02)	0.30 (0.02)	0.30 (0.02)	0.30 (0.02)
-2*log likelihood	1390.11	1364.82	1364.75	1360.54
Change in -2*log likelihood		-25.29***	-0.01^{ns}	-4.21^{ns}

Note. N = 830, M = 1.51, SD = 0.56; Response options are 1 = Technology, 2 = both Technology and Science, and 3 = Science; Level 1 and Level 2 values pertain to unstandardized beta values (β); unstandardized errors are in parentheses; NCEA exp. = National Certificate for Educational Achievement experience; ^{ns} = not statistically significant, *p < .05, **p < .01, ***p < .001; changes in degrees of freedom taken into account when estimating significance of change in -2*log likelihood; (estimations calculated to 3 decimal places, final rounding to 2).

In summary, all ITEs consistently agreed with the central tenet that design is a process that can turn ideas into products. Likewise, ITEs generally thought that Technology had quite a heavy focus on creativity, design, and showing others your ideas; however, graduate ECE ITEs were slightly less inclined to think that way. Overall, respondents thought that creativity was largely more applicable to Technology; however, older ITEs and male ITEs were more likely to see the relevance of creativity in Science.

Discussion

A clear understanding of Technology is important. Perceptions of a discipline play an important role in what is taught and learnt in classrooms (Rohaan, Taconis, & Jochems, 2010; Stein, McRobbie, & Ginns, 2000). Students, teachers and parents need to have a sound notion of what the subject is and why it is needed (Wicklein, 2006). Compared with traditional subjects such as science and mathematics, technology is a relatively new learning area to the school curriculum (Ferguson, 2009; Jones, 2003). It is, therefore, not surprising that many people do not fully understand what the subject entails (Compton & Compton, 2013; Sanders, 2009). However, results herein suggest that ITE students generally have a firm grasp of the fundamental principles of Technology, and the processes of learning within the subject.

Technology is multifaceted and interdisciplinary by nature (O'Sullivan, 2010). Due to its practical, and hands-on nature, design and creativity are seen as integral components of the subject (Bäckström et al., 2013; Fox-Turnbull, 2010; Neo & Neo, 2013; Pavlova, 2005). Design assists the development of a creative product which is original, aesthetic, useful, functional and valuable (Casakin & Kreitler, 2011; Christiaans, 2002). Therefore, the consistency with which all student teacher groups quite firmly agreed with the notion that *Design is a process that can turn ideas into products* places them in good stead as they transition to educating youth in New Zealand. It appears that a fundamental understanding of the role that design plays in technology education has been instilled across the board, so tertiary curricula need not focus on developing this fundamental understanding among students on entry.

Creativity includes skills such as creative thought processes, creative learning, creative problem-solving, creative thinking as well as possibility and imaginative thinking (Davies et al., 2013). Although both design and creativity are interwoven and seen as fundamental aspects of technology education (Cropley & Cropley, 2010), they do not happen as a matter of course and therefore must be carefully planned (Thorsteinsson & Page, 2015). Teachers need a diverse range of strategies and an awareness of the importance of creating an environment which fosters design and creativity (Csikszentmihalyi, 1996; Kaufman & Beghetto, 2009; Wu, 2004). Findings in this study suggest that ITE students' generally consistent perception that technology has a strong focus on creativity, design and sharing ideas also generally places them in a sound position on entry. Although, it should be noted that, *ceteris paribus*, those students undertaking graduate diplomas in early childhood education were less inclined to agree with this central idea. Implications of this finding are discussed in the following subsection.

A final result of this study was that, from the perception of ITE students, creativity is seen as far more relevant to Technology than Science, although, interestingly, older males tended to see more relevance of creativity in both Technology and Science. The reason for this may be that older males, perhaps having more extensive work experience in multiple industries, are more readily able to see the possibilities for creativity in scientific endeavour (of course, follow up studies would need to help determine exactly why those particular cohorts more readily saw the relevance of creativity in Science).

Conclusion and Implications for Practice

The main finding from this study is that ITE students, upon entry to educational programs, generally seem to have a firm grasp of the fundamental principles of Technology and the processes of learning within the discipline—the turning of ideas into products. However, given the analysis of various factors of the conceptions measured in this study, some curricula adaptations could be made to the start of programs catering to graduate ECE ITE students to account for their lack of understanding that Technology is about creativity, design, and showing others your ideas. Policy makers and curricula designers could provide this cohort with more explicit examples of exemplary projects undertaken in the technology classroom (see Microsoft New Zealand News Centre, 2016, for example). Doing so may enable these future teachers to provide for imaginative, collaborative work that generates innovations and possibilities for the future.

Because all ECE and primary school teachers are also responsible for Science, curricula designers might also consider imbuing these trainees with an understanding that both domain-specific knowledge and creativity are essential to success in Science (Rowlands, 2011), and that creativity can be a part of a science curriculum (Hadzigeorgiou, Fokialis, & Kabouropoulou, 2012).

When teachers provide space for creativity and imagination in Technology and Science, they are able to engage and motivate students (McLellan & Nicholl, 2013), resulting in increased academic achievement (Craft, 2005; Robinson, 1999), better employment prospects in STEM (Ejiwale, 2012), and business success (Department for Culture, 2008). With this notion in mind, we leave with the following Māori proverb:

> *Ka tipu te whaihanga* [Creativity will strengthen]

Together with a good understanding we can support the creative learners of tomorrow.

Affiliations

Matthew Courtney
Research Fellow
University of Melbourne
matthew.courtney@unimelb.edu.au

Kerry Lee
Lecturer
The University of Auckland
k.lee@auckland.ac.nz

Anne McGlashan
Lecturer
The University of Auckland
a.mcglashan@auckland.ac.nz

Meripa Toso
Lecturer
The University of Auckland
m.toso@auckland.ac.nz

Paul Neveldsen
Lecturer
The University of Auckland
p.neveldsen@auckland.ac.nz

References

Addison, N., Burgess, L., Steers, J., & Trowell, J. (2010). *Understanding art education: Engaging reflexively with practice*. New York, NY: Routledge.

Almutairi, A., Everatt, J., Snape, P., & Fox-Turnbull, W. (2014). Exploring the relationship between science and technology in the curriculum. *Australasian Journal of Technology Education*, *1*(1). doi:http://dx.doi.org/10.15663/ajte.v1i1.16

Atkinson, S. (2000). Does the need for high levels of performance curtail the development of creativity in design and technology project work? *International Journal of Technology and Design Education, 10*, 255–281. doi:10.1023/A:1008904330356

Bäckström, M., Tinnsten, M., Koptyug, A., Rännar, L.-E., Carlsson, P., Danvind, J., & Wiklund, H. (2013). Sports technology education at mid Sweden University. *Procedia Engineering, 60*, 214–219. doi:http://dx.doi.org/10.1016/j.proeng.2013.07.037

Barak, M., & Shachar, A. (2008). Projects in technology education and fostering learning: The potential and its realization. *Journal of Science Education and Technology, 17,* 285–296. doi:10.1007/s10956-008-9098-2

Barton, A. C., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls. *American Educational Research Journal, 45,* 68. doi:10.3102/0002831207308641

Blikstein, P. (2013). Digital fabrication and 'making' in education: The democratization of invention. In J. Walter-Herrmann & C. Büching (Eds.), *FabLabs: Of machines, makers and inventors.* Bielefeld, Germany: Transcript.

Brown, R. A., & Brown, J. W. (2010). What is technology education? A review of the Official Curriculum. *The Clearing House: A Journal of Educational Studies, 83*(2), 49–53. doi:10.1080/00098650903505449

Casakin, H., & Kreitler, S. (2011). The cognitive profile of creativity in design. *Thinking Skills and Creativity, 6*(3), 159–168. doi:10.1016/j.tsc.2011.06.001

Christiaans, H. H. (2002). Creativity as a design criterion. *Communication Research Journal, 14*(1), 41–54. http://dx.doi.org/10.1080/10400410902861471

Compton, V., & Compton, A. (2013). Teaching the nature of technology: Determining and supporting student learning of the philosophy of technology. *International Journal of Technology and Design Education, 23*(2), 229-256. doi:10.1007/s10798-011-9176-2

Constantinou, C., Hadjilouca, R., & Papadouris, N. (2010). Students' epistemological awareness concerning the distinction between science and technology. *International Journal of Science Education, 32*(2), 143–172. doi:10.1080/09500690903229296

Craft, A. (2005). *Creativity in schools: Tensions and dilemmas*. London, England: Routledge.

Crooks, T., Smith, J., & Flockton, L. (2007). *Science Assessment Results 2007: NEMP Report 44*. Dunedin, New Zealand: Educational Assessment Research Unit. Retrieved from http://nemp.otago.ac.nz/science/2007/index.htm

Cropley, D., & Cropley, A. (2010). Recognizing and fostering creativity in technological design education. *International Journal of Technology and Design Education, 20*(3), 345–358. doi:10.1007/s10798-009-9089-5

Csikszentmihalyi, M. (1996). *Flow and the psychology of discovery and invention*. New York, NY: Harper Collins.

Davies, D., Jindal-Snape, D., Collier, C., Digby, R., Hay, P., & Howe, A. (2013). Creative learning environments in education: A systematic literature review. *Thinking Skills and Creativity, 8*, 80–91. doi:10.1016/j.tsc.2012.07.004

Department for Culture, M. a. S. (2008). *Creative Britain: New Talents for the creative economy*. London, England: Department for Culture, Media and Sport. Retrieved from http://webarchive.nationalarchives.gov.uk/+/http:/www.culture.gov.uk/images/publications/CEPFeb2008.pdf.

DeHaan, R. L. (2009). Teaching creativity and inventive problem solving in science. *CBE-Life Sciences Education*, *8*(3), 172–181. doi: 10.1187/cbe.08-12-0081

Dorst, K., & Cross, N. (2001). Creativity in the design process: Co-evolution of problem–solution. *Design Studies*, *22*(5), 425–437. http://dx.doi.org/10.1016/S0142-694X(01)00009-6

Ejiwale, J. A. (2012). Facilitating teaching and learning across STEM fields. *Journal of STEM Education: Innovations and Research, 13*(3), 87–94.

Ferguson, D. (2009). *Development of technology education in New Zealand schools 1985–2008*. Wellington, New Zealand: Ministry of Education.

Forret, M., Fox-Turnbull, W., Granshaw, B., Harwood, C., Miller, A., O'Sullivan, G., & Patterson, M. (2013). Towards a pre-service technology teacher education resource for New Zealand. *International Journal of Technology and Design Education, 23*(3), 473–487. doi:10.1007/s10798-011-9199-8

Fox-Turnbull, W. (2010). The role of conversation in technology education. *Design and Technology Education, 15*(1), 24–30.

Gandini, L., Hill, L., Cadwell, L., & Schwall, C. (Eds.). (2005). *In the spirit of the studio: Learning from the atelier of Reggio Emilia*. New York, NY: Teachers College Press.

Goldman, D., Yavetz, B., & Pe'er, S. (2014). Student teachers' attainment of environmental literacy in relation to their disciplinary major during undergraduate studies. *International Journal of Environmental & Science Education, 9*(4), 369–383. doi:10.12973/ijese.2014.22a

Granshaw, B. (2015). Perspectives on technology education in New Zealand: Twenty years of progress? *Australasian Journal of Technology Education, 2*(1), 2–14. doi:10.15663/ajte.v2i1.26

Gregory, S.A. (1966) Design science. In S.A. Gregory (ed.). *The design method* (pp. 323-330). London, England: Butterworth.

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. New York, NY: Routledge.

Hadzigeorgiou, Y., Fokialis, P., & Kabouropoulou, M. (2012). Thinking about creativity in science education. *Creative Education*, *3*(5), 603.

Jones, A. (2003). The development of a national curriculum in technology for New Zealand. *International Journal of Technology and Design Education, 13*, 83–99. doi:10.1023/A:1022355410425

Jones, A., Buntting, C., & de Vries, M. (2013). The developing field of technology education: A review to look forward. *International Journal of Technology and Design Education, 23*(2), 191–212. doi:10.1007/s10798-011-9174-4

Kaufman, J., & Beghetto, R. (2009). Beyond big and little: The four c model of creativity. *Review of General Psychology, 13*(1), 1–12. doi:10.1037/a0013688

Kind, P. M., & Kind, V. (2007). Creativity in science education: Perspectives and challenges for developing school science. http://dx.doi.org/10.1080/03057260708560225

Koster, B., Brekelmans, M., Korthagen, F., & Wubbels, T. (2005). Quality requirements for teacher educators. *Teaching and Teacher Education, 21*(2), 157–176. doi:10.1016/j.tate.2004.12.004

Lewis, T. (1995). From manual training to technology education: The continuing struggle to develop a school subject in the USA. *Journal of Curriculum Studies, 27*(6), 621–645. doi:10.1080/0022027950270603

Lin, T. C., Tsai, C. C., Chai, C. S., & Lee, M. H. (2013). Identifying science teachers' perceptions of technological pedagogical and content knowledge (TPACK). *Journal of Science Education and Technology*, *22*(3), 325–336. doi:10.1007/s10956-012-9396-6

Little, R. J. A. (1988). A test of missing completely at random for multivariate data with missing values. *Journal of the American Statistical Association, 83*(404), 1198–1202. doi:10.1080/01621459.1988.10478722

Longshaw, S. (2009). Creativity in science teaching. *School Science Review*, *90*(332), 91–94.

Martin, G., & Ritz, J. (2012). Research needs for technology education: A US perspective. *Journal of Technology Education, 23*(2), 25-43.

McLellan, R., & Nicholl, B. (2013). Creativity in crisis in design & technology: Are classroom climates conducive for creativity in English secondary schools? *Thinking Skills and Creativity, 9*, 165–185. doi:10.1016/j.tsc.2012.11.004

McWilliam, E., & Haukka, S. (2008). Educating the creative workforce: New directions for twenty□first century schooling. *British Educational Research Journal, 34*(5), 651–666. doi:10.1080/01411920802224204

Medway, P. (1989). Issues in the theory and practice of technology education. *Studies in Science Education, 16*, 1–24. doi:10.1080/03057268908559958

Microsoft New Zealand News Centre (2016). Kiwi students open windows to the future with innovative tech ideas. Retreived from https://news.microsoft.com/en-nz/2016/07/01/kiwi-students-open-windows-to-the-future-with-innovative-tech-ideas/#sm.000016eu027gjddvkq5bn6mec8luv#AX3kvJwhUCWc4po5.97

Ministry of Education. (1993). *Technology in the New Zealand curriculum. Draft*. Wellington, New Zealand: Learning Media.

Ministry of Education. (1995). *Technology in the New Zealand curriculum*. Wellington, New Zealand: Learning Media.

Ministry of Education. (2007). *The New Zealand Curriculum*. Wellington, New Zealand: Learning Media.

Ministry of Education. (2014). What is Science About? Retrieved from http://nzcurriculum.tki.org.nz/The-New-Zealand-Curriculum/Science

Neo, M., & Neo, T. (2013). Exploring students' creativity and design skills through a multimedia project: A constructivist approach in a Malaysian classroom. *Design and Technology Education: An International Journal, 18*(3), 48.

Education Review Office (2012). Science in the New Zealand Curriculum: Years 5 to 8. Retrieved from http://www.ero.govt.nz/assets/Uploads/Science-in-the-New-Zealand-Curriculum-Years-5-to-8.pdf

O'Sullivan, G. (2010). Technology education in New Zealand: The connected curriculum. *Design and Technology Education: An International Journal, 15*(1), 31–39.

Pavlova, M. (2005). Social change: How should technology education respond? *International Journal of Technology and Design Education, 15*(3), 199–215. doi:10.1007/s10798-004-5867-2

Piffer, D. (2012). Can creativity be measured? An attempt to clarify the notion of creativity and general directions for future research. *Thinking Skills and Creativity, 7*(3), 258–264. doi:10.1016/j.tsc.2012.04.009

Rabash, J., Steele, F., Browne, W. J., & Goldstein, H. (2012). A users guide to MLwiN (v2.26). London, England: Multilevel Models Project, University of London.

Robinson, K. (1999). *All our futures: Creativity, culture and education*. London, England: DFEE.

Rohaan, E. J., Taconis, R., & Jochems, W. M. (2010). Reviewing the relations between teachers' knowledge and pupils' attitude in the field of primary technology education. *International Journal of Technology and Design Education, 20*(1), 15–26. doi:10.1007/s10798-008-9055-7

Rowlands, S. (2011). Discussion article: Disciplinary boundaries for creativity. *Creative Education*, *2*(01), 47. doi:10.4236/ce.2011.21007

Sanders, M. (2009). STEM, STEM education, stemmania. *The Technology Teacher, 68*(4), 20–26.

Schmidt, A. L. (2011). Creativity in science: Tensions between perception and practice. *Creative Education*, *2*(05), 435. doi:10.4236/ce.2011.25063

Schneider, C., Pakzad, U., & Schlüter, K. (2013). The influence of personal school experience in biology classes on the beliefs of students in university teacher education. *Journal of Education and Training Studies, 1*(2), 19–210. doi:10.11114/jets.v1i2.146

Seltzer, K., & Bentley, T. (1999). *The creative age: Knowledge and skills for the new economy*. London, England: Demos.

Skophammer, R., & Reed, P. A. (2014). Technological literacy courses in pre-service teacher education. *The Journal of Technology Studies, 40*(2), 68–81.

Stein, S., McRobbie, C., & Ginns, I. (2000). Recognising uniqueness in the technology key learning area: The search for meaning. *International Journal of Technology and Design Education, 10*(2), 105–123. doi:10.1023/A:1008945013123

Thorsteinsson, G., & Page, T. (2015). How do practising teachers understand creativity? *International Journal of Teaching and Case Studies, 6*(1), 61–77. doi:10.1504/IJTCS.2015.069768

Vossoughi, S., Escudé, M., Kong, F., & Hooper, P. (2013). Tinkering, learning & equity in the after-school setting. In *Annual FabLearn conference.* Palo Alto, CA: Stanford University.

Wicklein, R. C. (2006). Five good reasons for engineering as the focus for technology education. *The Technology Teacher, 65*(7), 25–29.

Williams, P. J. (2011). STEM education: Proceed with caution. *Design and Technology Education, 16*(1), 26–35.

Wu, J. J. (2004). Recognizing and nurturing creativity in Chinese students. In S. Lau, A. N. N. Hui, & G. Y. C. Ng (Eds.), *Creativity: When east meets west* (pp. 169–200). Singapore: World Scientific Publishing.