Creativity and Innovation in STEM Education

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Creativity *and* Innovation in STEM Education

Guest Editor
Fredricka Reisman, PhD

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Creativity and Innovation in STEM Education

KIE Conference Publications

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Bonnie Cramond
Bonnie Cramond is a professor of Educational Psychology/Gifted and Creative Education at the University of Georgia. She has been a member of the Board of Directors of the National Association for Gifted Children, director of the Torrance Center for Creativity and Talent Development, editor of the Journal of Secondary Gifted Education, and a classroom teacher. Currently on the advisory board for the American Creativity Association, the Future Problem Solving Program International, and a member of the Japan International Creativity Society, she is on the review board for several journals and is a survivor of parenting two gifted and creative people. Bonnie has won several awards for her work, most recently the Lifetime Achievement Award from the American Creativity Association in 2017. An international and national speaker, she has published numerous articles and chapters and a book on creativity research, and teaches classes on giftedness and creativity. She is particularly interested in the identification and nurturance of creativity, especially among individuals considered at risk because of their different ways of thinking, such as those misdiagnosed with ADHD, emotional problems, or those who drop out.

Chris Wilson
Chris Wilson is a member of the academic team in the Centre for Learning Innovation and Professional Practice (CLIPP) at Aston University in the UK and a Principal Fellow of the Higher Education Academy. Leading the development of teaching practice through accredited postgraduate qualifications and professional recognition schemes with the centre, Chris remains heavily involved with a range of institutional learning and teaching projects and in the wider sector. He is a classically trained violinist, composer and practitioner in the technological arts, and has published, and presented internationally on the subjects of creativity, artistry, project management, and education, over a twenty-year career in higher education.

Christine Galib
Christine Galib is a doctoral candidate at Drexel University and director of Entrepreneurship and Wellness Programs at The Village School, Houston, Texas, USA. After co-founding a successful investment management team on Wall Street, Christine Galib taught science, health & wellness, and yoga through Teach For America. A nationally certified Integrative Nutrition Health Coach and yoga teacher, Ms. Galib founded Plan My Plate, a health & wellness consulting firm offering workshops on diet and exercise, stress management, mindfulness, and meditation. Ms. Galib has given presentations on wellness in corporate, hospital, and university settings, and teaches classes on mindfulness and meditation at Rice University's Susanne M. Glasscock

School of Continuing Studies. Ms. Galib also serves as the Director of Curriculum and Instruction at Bridges to Wealth, a social enterprise closing the wealth gap through teaching business literacy, entrepreneurship, and investing. Ms. Galib is thrilled to serve as Director of Entrepreneurship and Wellness Programs at The Village School. She holds her A.B. from Princeton University and M.S.Ed. from the University of Pennsylvania Graduate School of Education, where she serves as an instructor. She is pursuing her EdD in Educational Leadership and Management, with a concentration in Creativity and Innovation, at Drexel University.

Darren Stoddart
Darren Stoddart is active in music composition, visual arts, theatre arts, and new product development. He has led creativity and design workshops at The Kansas City Art Institute, Milwaukee Institute of Art and Design, Southern Illinois University - Carbondale, University of Notre Dame, and The School of the Art Institute of Chicago. Darren started his professional career as an industrial designer earning six patents for his work. Today he is a Senior Director of Innovation and New Product Development at Masco Coatings, the maker of BEHR Paint and KILZ Primers. He is currently working towards his Masters of Science degree in Creativity and Innovation through Drexel University, writing new material with his band, sculpting and carving South Pacific influenced artifacts, and building special effects, props, and sets for two local theatre companies.

Erik E. Guzik
Erik Guzik is co-founder and CEO of VAST: Next Generation Learning and executive director of the non-profit Virtual Problem Solving Program. Guzik received his PhD in economics from the University of Massachusetts Amherst. His research centers on the micro-foundations of creativity and software-based problem solving methodologies for improving learning outcomes and cognitive training. For his research into cloud-based learning and assessment, Guzik received the 2011 Creative Oklahoma Great Inspirations Award, the Oklahoma Journal Record's 2012 Creativity Award, and Hewlett Packard's 2012 Catalyst Showcase People's Choice Award.

Fredricka K. Reisman
Fredricka K. Reisman, Ph.D. is founder of Drexel's School of Education and is Emerita Professor in the School of Education. Additionally, Dr. Reisman served as Assistant Provost for Assessment and Evaluation, Interim Associate Dean for Research of the Goodwin College, and currently is Director of the Drexel/Torrance Center for Creativity and Innovation. Dr. Reisman received her Ph.D. in Mathematics Education from Syracuse University. Prior to coming to Philadelphia, Dr. Reisman served as Professor and Chair of the Division of Elementary Education at the University of Georgia and as an elementary, middle school, high school mathematics teacher in New York State, and

mathematics education instructor at Syracuse University. Dr. Reisman has an impressive record of external funding from the National Science Foundation (NSF), the US Department of Education, the PA Department of Education, and foundation support such as the Wallace Funds and the Anna E. Casey Foundation, to assist pre-and in-service teachers in developing their mathematics and technology skills both in regular and charter public schools including national projects. In 1984, Dr. Reisman headed the Drexel project management team for the Computer Applications in Teaching Program which was the first major effort to integrate computing into instruction in the Philadelphia high schools.

She recently completed her fifth year as ACA President (James Kaufman was installed ACA president in November 2017). She has worked with a team of instructional designers and software developers at Drexel to create simulations for pre and in service, teachers addressing school-age violence and classroom management. Dr. Reisman was a virtual keynote speaker at the KIE conference held in Riga, Latvia in July 22-15, 2014 (see http:// www.kiecon.org/page3.html). She also presented virtually at KIE conferences in London, Istanbul, and Berlin. The recent KIE conference was at Drexel in Philadelphia with participants from the UK, Finland, and several US locations. Dr. Reisman received the 2017 National Association for Gifted Children E. Paul Torrance Award with the following statement:

Fredricka Reisman's championing of creativity—as author, educator, test developer, and advocate—is consistent with Dr. Torrance's spirit and wisdom. She has been the long-time president of the American Creativity Association. She is an active scholar who has written numerous books and articles about STEM, learning, and creativity. She has successfully obtained funding in excess of $13M over the last 15 years towards improving mathematics and science creativity in K-12 schools. Keeping up with the times, Dr. Reisman recently developed the mobile app the Reisman Diagnostic Creativity Assessment. She worked extensively with Dr. Torrance at Georgia and continues to build off of his legacy. At Drexel, she founded the Drexel/ Torrance Center for Creativity and Innovation, the first Center outside of the University that had Dr. Torrance's personal permission to open.

James C. Kaufman

James C. Kaufman, PhD, is a Professor of Educational Psychology at the University of Connecticut. An internationally recognized leader in the field of creativity, he is the author/editor of more than 26 books, including Creativity 101 and the Cambridge Handbook of Creativity. Kaufman is the president of American Psychological Association's Division 10, which is devoted to creativity and aesthetics. He is the founding co-editor of Psychology of Popular Media Culture and co-founded Psychology of Aesthetics, Creativity, and the Arts, both published by APA. He has won numerous awards, including the Torrance Award from the National Association for Gifted Children, the Berlyne and Farnsworth Awards from APA, and Mensa's research award.

Kathy Goff
Kathy Goff is the President of McGoff Creativity and Chief Creative Officer/ Co-founder of Vast Learning Systems, a cloud-based edtech software company that focuses on creativity assessments and brain trainings. She earned a doctorate at the University of Georgia in Adult Learning and Creativity under Dr. E.Paul Torrance, the “Father of Creativity”. Kathy served as Torrance’s personal research assistant and collaborator for over 16 years. Goff and Torrance (2000) created the Abbreviated Torrance Test for Adults (ATTA), one of the first instruments to measure creativity in adults. She is an internationally recognized author, researcher, educator, patented inventor, consultant and entrepreneur with over 3 decades of experience researching the creativity of people of all ages and backgrounds.

Kuan Chen Tsai
Kuan Chen Tsai received his PhD from the program of Organizational Leadership at the University of Incarnate Word (UIW) where he also worked as teaching and research assistant. He currently is an assistant professor in the Art and Design Department at the City University of Macau (CUM). He is the member of the American Creativity Association. He is also the author of numerous journal articles and several book chapters. His research interests include creativity, adult learning, organizational behavior, and art & design.

Larry Keiser
Larry Keiser is the Executive Director of Special Projects, Communications & Administration for Drexel University's School of Education. He has been with Drexel 32 years in various positions with a focus throughout on new program development, obtaining externally funded projects, and developing partnerships with Philadelphia organizations and schools. These programs, projects and partnerships promote alternative preparation pathways of K-12, STEM teachers, provide professional development toward school leadership improvement; enhance pre-service and in-service teachers' and elementary/ secondary students' mathematics and science content knowledge; better incorporate appropriate technology into the K-16 teaching and learning process; and promote creativity and innovation in schools, the workplace and in life. Larry presents nationally and internationally on the need to infuse creativity and innovation into K-16 education. He serves as adjunct instructor in the School’s Creativity and Innovation Program for courses on the Foundations of Creativity.

Laura Kathleen Personette
Laura Kathleen Personette combines creativity, empowerment, and youth leadership development with STEM (science, technology, engineering, and math) in 4-H’s Community Central program in the University of Maine's Cooperative Extension. Laura began her career in youth leadership mentoring through service to AmeriCorps. She holds a Master's Degree in Leadership

Studies from the University of Southern Maine and is an alumnus of USM's leadership development program in South Africa (The Montagu Project). Laura continues to work with The Montagu Project and is an adjunct professor for the Leadership Studies program.

Mary Anne Peabody

Mary Anne Peabody is an Assistant Professor of Social and Behavioral Sciences at the University of Southern Maine. Her professional training and experience span the fields of Clinical Social Work and Executive Leadership. Her research focuses on the impact of community engagement and facilitated communication, play therapy, and playful pedagogy. She has researched and published on the adaptation of Lego® Serious Play® in clinical supervision, training, and higher education. She is a licensed clinical social worker and a Registered Play Therapist-Supervisor. She is a Past-President of the National Association of Play Therapy.

Michael Brown

Michael Brown is the Programme Leader for the BA (Hons) Music degree in the College of Arts, at the University of Derby in the UK. He holds diplomas in both Art and Music, a BSc (Hons) degree in Software Engineering, Mathematics and Music, and a Masters degree in Contemporary Composition, which combine to serve his interest in computer creativity. He is a Principal Researcher with over twenty-five years of teaching experience, an active artist, composer and musician. As well as maintaining his professional role, he is a member of the American Creativity Association and has presented his research in multimodal creativity internationally.

Peter Lennox

Peter Lennox PhD (University of York) is a Senior Lecturer at the University of Derby, teaching and researching in auditory perception and spatial psychoacoustics. He has a background in the oil industry, heavy engineering, corrosion engineering, and theatre and film production. He has lectured at University of York, Bretton Hall, Sheffield Hallam University, and the University of Derby. He held the post of Director of the Signal Processing Applications Research Group (SPARG) at the University of Derby from 2003 to 2010. His has special interests in the philosophy of the scientific study of perception.

Rex Jung

Rex Jung is an Assistant Professor in the Department of Neurosurgery at the University of New Mexico, and a neuropsychologist in private practice at Brain and Behavioral Associates, PC. He received his PhD in Clinical Psychology from the University of New Mexico and performed an internship at the Baylor College of Medicine. He is the author of over 100 research papers exploring the relationship between complex cognitive processes - including intelligence, creativity, and personality - and brain structure and function. He has been Principal Investigator on projects funded by the National Institutes of Health, Templeton Foundation, and National Endowment for the Arts.

Rick Kantor

You know how some people always knew what they wanted to be? Rick Kantor wasn't one of them. His eclectic path to teaching Creativity and Innovation at Drexel University is strewn with entrepreneurial ventures in product design for the Gift Industry, retail furniture stores in Manhattan, a decorative painting and mural business, an international Halloween manufacturing company which also designed exclusive headwear for famous Theme Parks and Cirque du Soleil. In between, he earned degrees in Psychology, Modern Dance, a Bachelor of Fine Arts in Painting and a 2015 Masters in Creativity and Innovation from Drexel University. AT LAST! Rick found his purpose in catalyzing creativity to others through teaching, public speaking, and consulting. Creativity is life…the rest is just details.

Tara Grey Coste

Tara Grey Coste is a Leadership and Organizational Studies professor at the University of Southern Maine. Her work focuses on refining the training processes that enhance creativity in teams and teaching individuals techniques to enhance leadership abilities in multi-cultural, multi-national environments. She has shared her work at venues around the world. She is a Visiting Scholar at Singapore Management University's Wee Kim Wee Centre for Cultural Studies and Past-President of the American Creativity Association. She is the founder of her university's youth leadership development program in South Africa, The Montagu Project.

PREFACE

CREATIVITY AND INNOVATION IN STEM EDUCATION

> *In my experience as an executive and entrepreneur sitting on both sides of the creative/technology fence, I need to hire technologists who know how to collaborate in teams, express themselves coherently, engagingly and persuasively, understand how to take and apply constructive criticism, and how to tell a good story. I don't find these kids sitting alone at a lab table or buried in an algorithm. I find them taking art classes to understand how color and light really work, I find them in writing classes learning how to express themselves, I find them in cultural studies and critical theory classes learning about the world at large.*
> - John Tarnoff, (2010, paras. 8-9)

STEM was an initiative of the National Science Foundation, an agency of the US government. STEM started as SMET – Science, Mathematics, Engineering and Technology (Saunders, 2009); its goal was to 'provide students with critical thinking skills that would make them creative problem solvers and ultimately more marketable in the workforce' (White, 2014, p.2).

The keyword in STEM education is 'integration', the integration of science, technology, engineering and mathematics curriculum to help students to develop requisite skills in science, mathematics, and analytical thinking (Maslen, 2017). When students are taught – and understood – how to integrate skills from STEM subjects, they are likely to be work-ready or best able to apply knowledge in a variety of contexts to both familiar and unfamiliar real-world situations.

At the heart of STEM education is creativity, which is a feedstock for innovation (Ogunleye & Tankeh, 2006; Tankeh & Ogunleye, 2006). Ramirez (2013) characterised creativity as the 'secret sauce' to science, technology, engineering and mathematics education. Creativity and innovation in STEM are essentially enablers – enabling students not only to know or understand 'hard sciences', but also to develop the 'ability to look at a situation from new and creative angles and express concepts and information clearly' (Ramirez, 2013, para. 3). Indeed, in recent time, there has been policy efforts, initiatives, programmes, empirical studies etc by policy makers, school administrators, academics and practitioners to promote and encourage creativity in teaching and learning in STEM education with an emphasis on the letter 'A' in the STEM/STEAM acronym – see, for example, Kelton & Saraniero (2018); Oner, et al. (2016); Kim & Chae (2016); Henriksen, (2014; 2017); Kang & Kim (2013); Kim, et al. (2012); Tarnoff (2010).

This KIE Conference book adds to the growing body of knowledge about creativity and innovation in STEM education. So, as always, on behalf of the KIE conference family, I say thank you to everyone who has contributed to this book; special thanks to Dr Fredricka Reisman for her sterling work in editing the book. Special thanks also to Dr James Kaufman, whose first chapter sets the tone for the book.

James Ogunleye, PhD, FRSA
Chairman, 2018 KIE Conference
Convenor, E. Paul Torrance International Roundtable on Creative Thinking
Convenor, Reisman Diagnostic Creativity Assessment Special Interest Group

References

Henriksen, Danah (2014) 'Full STEAM Ahead: Creativity in Excellent STEM Teaching Practices,' *The STEAM Journal*, 1 (2), Article 15. Available at: http://scholarship.claremont.edu/steam/vol1/iss2/15 (accessed: 30/6/18)

Henriksen, D. (2017). 'Creating STEAM with Design Thinking: Beyond STEM and Arts Integration,' *The STEAM Journal*, 3 (1), Article 11. Available at: http://scholarship.claremont.edu/steam/ vol3/ iss1/11 (accessed: 30/6/18)

Kang, M., Jang, K., & Kim, S. (2013). Development of 3D actuator-based learning simulators for robotics STEAM education. International Journal of Robots, Education and Art, 3(1), pp.22-32.

Kim, E., Kim, S., Nam, D., & Lee, T. (2012). Development of STEAM program Math centered for Middle School Students. Available at: http://www.steamedu.com/wpcontent/uploads/2014/12/ Development-of-STEAM-Korea-middle-school-math.pdf (accessed: 30/6/18)

Kim, H. & Chae, D.H. (2016) The Development and Application of a STEAM Program Based on Traditional Korean Culture, EURASIA J. Math., Sci Tech. Ed, 12(7), pp.1925–1936. DOI: https:// doi.org/10.12973/eurasia.2016.1539a

Maslen, C. (2017, January 26) **'**How STEAM Education Can Help Shape the Creative Leaders of Tomorrow', *Samsun Business Insights*, available at: https://insights.samsung.com/2017/01/26/how-steam-education-can-help-shape-the-creative-leaders-of-tomorrow/ (accessed: 30/6/2018)

Ogunleye, J. and Tankeh, A. (2006) Creativity and innovation in IT Industry: an assessment of trends in research and development expenditures and funding with particular reference to IBM, HP, Dell, Sun, Fujitsu and Oracle, *Journal of Current Research in Global Business*, vol. 9, 14, pp 75-85, Fall 2006.

Oner, A. T., Nite, S. B., Capraro, R. M., & Capraro, M. M. (2016). 'From STEM to STEAM: Students' Beliefs About the Use of Their Creativity,' *The STEAM Journal*, 2 (2), pp.1-14, Article 6. Available at: http://scholarship.claremont.edu/steam/vol2/iss2/6

Ramirez, A. (2013). 'Creativity is the Secret Sauce in STEM', *Edutopia*, *George Lucas Educational Foundation*, available at: https://www.edutopia.org/blog/creativity-secret-sauce-in-stem-ainissa-ramirez (accessed: 30/6/2018)

Sanders, M. (2009) STEM, STEM education, STEMmania. *The Technology Teacher*, 68(4), pp.20-26.

Tankeh, A. and Ogunleye, J. (2007) The Server Market: Innovation, Competitive Performance and Optimal Strategy in the face of 'Disruptive Innovation', *Conference Proceedings (Peer-Reviewed), 19th Annual Conference of the Association for Global Business*, Nov 15-18, 2007, Washington DC, USA.

Tarnoff, J. (2010, October 14). STEM to STEAM -- Recognizing the Value of Creative Skills in the Competitiveness Debate. Available at: http://stematehs.pbworks.com/w/file/fetch/46306554/ STEM2STEAM_Creativity.pdf (accessed: 30/6/2018)

White, D. W. (2014). 'What Is STEM Education and Why Is It Important?', *Florida Association of Teacher Educators Journal,* 1 (14). pp. 1-9. Available: http://www.fate1.org/journals/2014/white.pdf (accessed: 10/6/18)

2018 *BEST PAPER RECOGNITION AWARDS*

The Best Paper Recognition Awards are presented to the individuals judged by the *Creativity Experts Panel* of the *KIE International Advisory Board* to have written the best papers appearing in the annual KIE creativity volume. The award criteria are: (a) broad interest, b) clear and scholarly presentation, c) APA format, d) research or essay focus, d) scholarly presentation). The following authors received KIE 2018 *Best Paper Recognition Awards*:

Winner
Kathy Goff, Erik Guzik & Rex Jung: Digital Creative Problem Solving: The Beyonders Program.

Runner-Up
Chris Wilson, Aston University, UK, Michael Brown & Peter Lennox, University of Derby, UK: Engineering creativity: Exploring disciplinary difference as the basis for new pedagogical ideas.

On behalf of the KIE Conference International Advisory & Review Board, I extend my congratulations to all the winners and I say a big well done to all the authors and co-authors in this volume.
James Ogunleye, PhD, FRSA
Chairman, 2018 KIE Conference

Acknowledgement
Creativity Expert Panel & Awards Judges
Fredricka Reisman, *PhD*, President, American Creativity Association Drexel University, USA & Professor Emeritus, Drexel University, USA
James Kaufman, PhD, In-coming President, American Creativity Association & a Professor of Educational Psychology at the University of Connecticut, USA
Larry Keiser, Treasurer, American Creativity Association & Director of Special Projects & Certification Officer, Drexel University, USA
Gerard Puccio, *PhD,* Department Chair and Professor, International Center for Studies in Creativity, Buffalo State University of New York, USA

INTRODUCTION

FREDRICKA REISMAN

James Kaufman, president of the American Creativity Association as well as prolific researcher and author, kicks off the 2018 KIE conference book with his provocative essay entitled: *Creativity and STEM: Moving Beyond the Arts Bias*. Kaufman points out that "recognizing and valuing STEM creativity is a key part of helping our society flourish."

Next, Christine Galib presents Conversations with Directors on Creating a Sustainable STEAM Culture. In the author's role as Director of Entrepreneurship and Wellness Programs at The Village School, a Nord Anglia Education School located in Houston, TX, she shares the perspectives of Directors at The Village School in creating a sustainable STEAM culture. This chapter explores the following questions: What is STEAM? How does STEAM promote more opportunities for creativity, innovation, and design thinking? Why is integrating STEAM in school settings crucial to educating our children for their futures? Each section in this chapter also provides five strategies and three activities for creating a STEAM culture in schools.

The chapter by Wilson, Brown and Lennox explores educational approaches associated with engineering and musical disciplines. Recognizing the complex intersections between music and engineering, notably in areas such as acoustics, psychoacoustics, music technology and sound recording, these subjects have been brought together to create new pedagogies. The authors investigate how a more musical approach to the study of engineering could inform the more effective development of creative engineers.

The chapter by Goff, Guzik and Jung asks whether the increasing focus on STEM/STEAM diminishes opportunities for students to exercise their creativity. On the other hand, the authors question whether the STEM/ STEAM curricular focus might open new avenues for creativity to be promoted within the K12 classroom. This chapter explores the concept of STEM/ STEAM in reference to 21st century learning skills. The specific skills addressed are creativity and innovation, digital learning, creative problem solving, collaboration and communication explored within a research framework. They conclude that focus on STEM/STEAM as a component of creative problem solving offers new opportunities to increase student creativity and other 21st century skills.

Next, Kuan Chen Tsai presents an exploratory study that examines the creative process of Chinese undergraduates in Macau. Kuan's research attempts to understand to what extent person, product, and press interact with each other, as well as to examine the relationship among cognitive styles, creative achievements, and creative environments.

Coste, Peabody and Personette, in their chapter enitled *Making the Old New Again: Infusing STEM Education with Deliberate Creativity,* provide a rich history of the 4-H experience. They quote six features that relate creativity to school science: divergent thinking, open-ended questioning, generation of unusual ideas, generation of metaphors, solving problems and puzzles, and designing devises and machines, and suggest that these features influence both the 4-H Experiential Learning Model and the process for Creative Problem Solving. The authors conclude that the mission of 4-H today remains in balance with its historical purpose as well as setting the stage for developing future leaders.

The chapter by Reisman, Cramond, Kantor and Stoddart that reflects the KIE Reisman Diagnostic Creativity Assessment (RDCA) SIG conference panel completes the chapter content of the 2018 KIE conference book. The SIG panel topic also serves as the chapter title: *The Power of Becoming Aware of Our Creative Strengths and Weaknesses—and How this Helped Us Cope with Life Changing Happenings!* Each of the authors experienced/ endured a challenge involving a life changing happening. These authors share how their own creativity helped them deal with their personal challenges.

The final chapter by Stoddart shares his journey into Rarotonga to learn about creativity within this unique island. His descriptions of his experiences will be a joyful read for the KIE conference participants.

Fredricka Reisman, Editor
Philadelphia, PA. USA

CHAPTER ONE

CREATIVITY AND STEM: MOVING BEYOND THE ARTS BIAS

JAMES KAUFMAN

Creativity has long been associated with the arts. When people think they are not creative, it is often because they do not write poetry, draw pictures, or play an instrument. Even with STEM fields being promoted in the schools, an art bias remains in laypeople (Glăveanu, 2014; Hass, 2014) to the extent that STEM fields are sometimes specifically seen as uncreative (Kaufman & Baer, 2004; Valenti, Masick, Cox, & Osman, 2016).

Of course, as this volume demonstrates, the possibilities for STEM creativity are endless. Why is it often overlooked or undervalued? Our society accepts what Paulos (1988) called "innumeracy." We live in a world where pseudoscience is accepted and science is treated with skepticism (Kaufman & Kaufman, 2018). Yet just as core definitions of creativity include both an originality component *and* a useful component (Hennessey & Amabile, 2010), so too must society embrace both aesthetic *and* functional creativity (Cropley, 2015).

One of the founding principles of my belief system is that creativity can be found anywhere – at any level of eminence (Kaufman & Beghetto, 2009) and across a multitude of domains (Baer & Kaufman, 2017). Indeed, recognizing and valuing STEM creativity is a key part of helping our society flourish. I am thrilled to see these new contributions and hope they are a continued part of renewed scholarship on this key topic.

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References

Baer, J., & Kaufman, J. C. (2017). The Amusement Park Theoretical Model of Creativity: An attempt to bridge the domain specificity/generality gap. In J. C. Kaufman, V. P. Glăveanu, & J. Baer (Eds.), *Cambridge handbook of creativity across domains* (pp. 8-17). New York: Cambridge University Press.

Cropley, D. (2015). *Creativity in engineering: Novel solutions to complex problems.* San Diego, CA: Academic Press.

Glăveanu, V. P. (2014). Revisiting the "art bias" in lay conceptions of creativity. *Creativity Research Journal*, *26*, 11-20.

Hass, R. W. (2014). Domain-specific exemplars affect implicit theories of creativity. *Psychology of Aesthetics, Creativity, and the Arts*, *8*, 44-52.

Hennessey, B. A. & Amabile, T. M. (2010). Creativity. *Annual Review of Psychology, 61*, 569-598.

Kaufman, A. B., & Kaufman, J. C. (Eds.) (2018). *Pseudoscience: The conspiracy against science.* Cambridge, MA: MIT Press.

Kaufman, J. C., & Baer, J. (2004). Sure, I'm creative – but not in mathematics!: Self-reported creativity in diverse domains. *Empirical Studies of the Arts, 22*, 143-155.

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond big and little: The Four C Model of Creativity. *Review of General Psychology, 13*, 1-12.

Paulos, J. A. (1988). *Innumeracy.* New York: Vintage.

Valenti, S. S., Masnick, A. M., Cox, B. D., & Osman, C. J. (2016). Adolescents' and emerging adults‘ implicit attitudes about STEM careers: "Science is not creative.: *Science Education International*, *27*, 40-58.

CHAPTER TWO

FULL STEAM AHEAD: CONVERSATIONS WITH DIRECTORS ON CREATING A SUSTAINABLE STEAM CULTURE

CHRISTINE GALIB

"All real change is grounded in new ways of thinking and perceiving. As Einstein said: 'We can't solve problems by using the same kind of thinking we used when we created them.'"
– Senge, Smith, Kruschwitz, Laur, & Schley, *The Necessary Revolution*

Abstract

As educational leaders, how do we teach new ways of thinking to solve 21st Century problems? An integrated approach that promotes cross-departmental learning, STEM education encourages learners to connect science disciplines and develop, practice, and apply curiosity, knowledge, and skills to observe, collect, analyze, and communicate data. Yet, focusing on the sciences is not enough. By adding the "A" for arts, STEAM empowers learners to imagine, implement, and communicate a broader range of applications for the sciences. What is STEAM? How does STEAM promote more opportunities for creativity, innovation, and design thinking? Why is integrating STEAM in school settings crucial to educating our children for their futures? This chapter examines how STEAM is implemented in all grades at The Village School, a private, coeducational, non-denominational, and international preK-12th grade school in Houston, TX. Through reflections from the Head of School, Division Heads, faculty, and students, this chapter profiles the innovative STEAM learning opportunities that create Village's sustainable STEAM culture.

Keywords: STEAM, creativity, innovation, school culture, future-focused learning

According to Obama (2015), "[Science] is more than a school subject, or the periodic table, or the properties of waves" (U.S. Department of Education). He is right. Science encompasses and is related to many disciplines, including science, technology, engineering, and math (STEM) fields. Science is "an approach to the world, a critical way to understand and explore and engage with the world, and then have the capacity to change that world" (U.S. Department of Education). Obama prioritized STEM education, articulating

"American students must move from the middle to the top of the pack in science and math" (U.S. Department of Education). The Committee on STEM Education focused on five areas:

> 1.) improving STEM instruction in preschool through 12th grade; 2.) increasing and sustaining public and youth engagement with STEM; 3.) improving the STEM experience for undergraduate students; 4.) better serving groups historically underrepresented in STEM fields; and 5.) designing graduate education for tomorrow's STEM workforce. (U.S. Department of Education)

This approach to STEM education integrates multiple life-stages of learners, as well as seeks to promote engagement in STEM and ensure STEM is accessible to all. Yet, many learners still face barriers to pursing STEM opportunities. According to a Pew Research Center survey, "about half of adults (52%) say the main reason young people [do not] pursue STEM degrees is they think these subjects are too hard" (Kennedy, Hefferon, & Funk, 2018, para. 1). Other reasons include the following: young people do not view STEM as useful to their careers (23%), they think STEM is too boring (12%), and they face barriers such high expenses for STEM education and limited access to resources (Kennedy, Hefferon, & Funk, 2018).

As educational leaders, how do we mitigate these barriers and change learner perceptions of STEM? A new framework – one that more holistically integrates a broader range of more diverse experiences for learners – is needed. By adding the "A" for arts, STEAM provides this more holistic framework. For many students, the arts are a door or a bridge to STEM subjects. Since STEAM can promote exploration in less procedural and more open-ended ways than STEM does, adding art invites students to activate their imagination in ways that STEM does not. Adding the arts also supports different aspects of learning. When teachers permit students to express themselves in academic settings through art, such as by drawing pictures or writing songs, students embed information in their minds in different ways. Integrating the arts supports long-term learning, practice, and application of knowledge (Lynch, 2018, para. 1). While there are specific content, knowledge, and skills related to becoming an expert in the arts, the arts can be more accessible, and perhaps less intimidating, entry points to STEM since art leverages the human experience to a greater degree than does STEM.

Art also is related to innovation. For Isaacson (2017), "Despite all the proselytizing by STEM-education advocates, the best innovators have historically been the ones who embrace art as well as science, who have a feel for poetry, in addition to processors" (para. 3). An appreciation and love for the arts, and a desire to integrate them seamlessly in lived, STEM-related experiences, highlights a “simple but profound principle of humanity: beauty matters” (Isaacson, 2017, para. 3). Not only does beauty matter, but it is also important to the humanities. Both beauty and the humanities are important to technology, especially when building a team of innovative problem solvers (Berridge, 2017).

According to Feldman (2015), STEAM “[sparks] students’ imagination, [helps] students innovate through hands-on STEM projects. . . [and promotes applying] creative thinking and design skills to these STEM projects so that students can imagine a variety of ways to use STEM skills into adulthood” (para. 5). STEAM does not just add art into the mix of STEM subjects. STEAM promotes skills in “creativity, design thinking, tech literacy, collaboration, and problem solving” (Feldman, 2015, para. 12). By promoting a wide range of skills, STEAM helps students develop “high-order design and engineering skills while allowing students to innovate, invent, and succeed on their terms. It forces students to produce original work using STEM but gives them the choice of how to do so and what to produce” (Feldman, 2015, para. 11). Letting students make choices about their own educational process, as they engage in this process, is a key differentiator between STEM and STEAM. A STEAM environment emphasizes exploratory, non-linear learning, process, and integration of creative problem solving approaches, rather than following directions in a linear way to generate a right or wrong answer. According to Rowe (2017), “STEAM-based activities bring together many different disciplines of learning to explain how everyday objects and processes work” (para. 2).

Educational leaders seeking to create a sustainable STEAM culture in schools must implement appropriate and relevant scaffolds to support this exploration. We must also leverage STEAM as framework that leads to new ways of thinking to solve 21st century problems. An integrated approach that promotes cross-discipline learning, STEM education encourages learners to make connections among their different subjects and develop, practice, and apply curiosity, knowledge, and skills to observe, collect, analyze, and communicate information. Yet, focusing on the sciences is not enough. By adding the “A” for the arts, STEAM empowers learners to imagine, implement, and communicate a broader and more creative range of applications for the sciences.

This chapter shares the perspectives of Directors at The Village School, a Nord Anglia Education school, in creating a sustainable STEAM culture. This chapter explores the following questions: What is STEAM? How does STEAM promote more opportunities for creativity, innovation, and design thinking? Why is integrating STEAM in school settings crucial to educating our children for their futures? Each section in this chapter also provides five strategies and three activities for creating a STEAM culture in schools.

A STEAM Foundation: STEAM in Early Childhood Education

A Conversation with Cynthia Bohrer, Director of Early Childhood

"Play is the highest form of research."
– Albert Einstein

"Children must be taught how to think, not what to think."
– Margaret Mead

Village's Early Childhood Division is called Finna, which comes from the Nordic word meaning "to discover." "Discovering" is exactly what Village's youngest students do on a daily basis. I had a chance to discuss STEAM with Cynthia. As I waited in Cynthia's office for our conversation to begin, I saw tubs and tubs brimming with objects, widgets, and gadgets, from Legos to sticks. For a young child, or a teacher looking for fun and engaging lesson materials, Cynthia's office is quite the treasure trove.

For Cynthia, STEAM is about creating opportunities for our youngest learners to explore and act on their curiosity in interdisciplinary and integrated ways. STEAM is about the process, experience, and exposure. It is also about the product, problem-solving skills, and people. "At its core, STEAM is about bringing people together to collaborate to solve a problem. Different people see events and patterns in different ways. They bring different perspectives, aptitudes, angles, filters, and intelligences to problem solving," said Cynthia. Approaching a problem from multiple perspectives is particularly important in early childhood settings, when students are also learning the basics and discrete skills. STEAM links these basics and discrete skills to problem solving skills, as one, complete experience. A STEAM approach permits children to explore and use their strengths while building skills in other areas and to partner with their peers, who may see or tackle a problem in a different way. "A STEAM approach is the foundation for authentic collaboration and child-driven inquiry. Early childhood is such an important time to help every learner develop these skills," explained Cynthia.

At Village, STEAM is neither a separate time of day, nor is it one, discrete activity. Rather, the entire Finna curriculum is based on thematic, interdisciplinary learning. Every class has STEAM objectives and activities aligned with those objectives. In this way, STEAM fits seamlessly into Village's educational program. STEAM is a dedicated effort from all teachers as part of the fabric of Finna's everyday culture and curriculum. It is this tightly and purposefully knit fabric that enables STEAM to be successful in early childhood.

For Cynthia, early childhood is the most exciting time in a child's life, since it is the start of a child's educational journey. "We strive to holistically build our youngest students' skills and aptitude. No one knows whether they're going to be a scientist or coder or artist just yet, and their limitless potential is the exciting part!" Long before children choose their college and careers, children learn in holistic ways. And, for Cynthia, it's very encouraging to see what happens when children require fewer prompts to think outside the box. "What happens, when, with a STEAM mindset, our two-year olds become four-year olds? What happens when teachers don't have to give students as many prompts to help them think outside the box? What happens when students just do it?"

With a STEAM mindset of "think, puzzle, explore" (see Figure 1), Village's youngest learners realize that they can solve a problem in ways that promote responses from multiple perspectives. To include these different perspectives, students have to collaborate – which they are very skilled at.

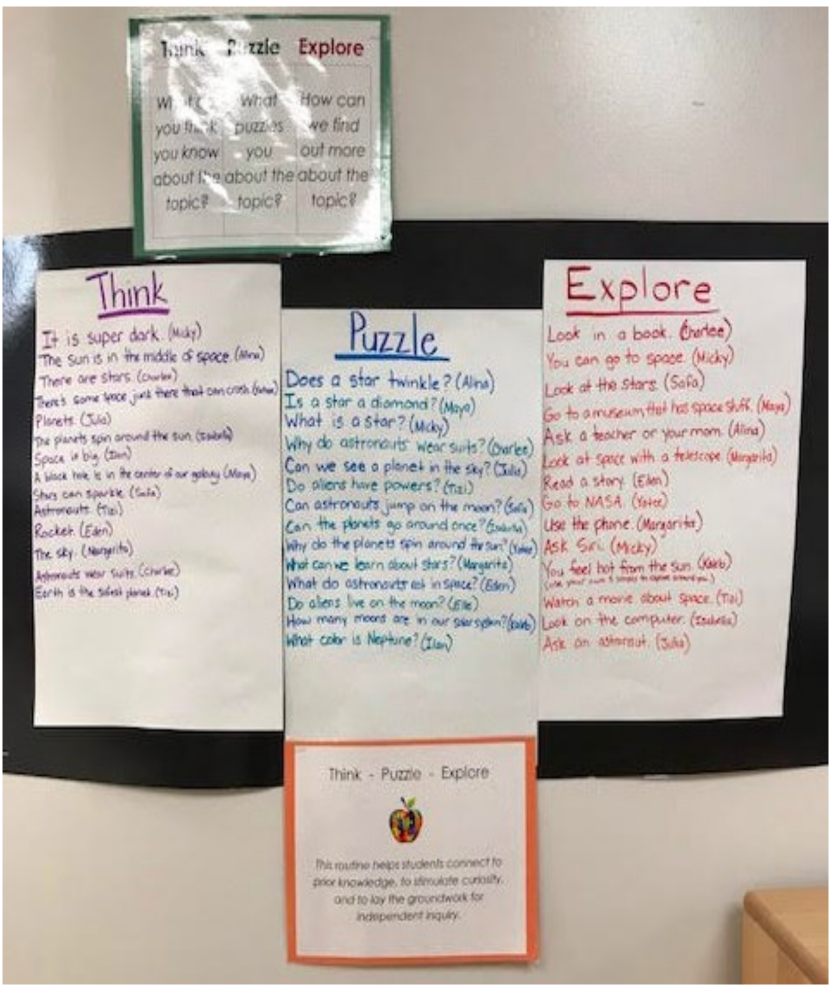

Figure 1 *Think, Puzzle, Explore.* With a "think, puzzle, explore" framework, students identify what they think they know about a topic, what puzzles them about the topic, and how they can find out more about the topic.

"Collaboration tends to favor the more verbal students," Cynthia cautioned. "We have to remember that language skills are just one piece of the STEAM puzzle. Group story telling and drama are also part of literacy. Could you act out a science concept? Draw a math problem?" Moving away from basing collaboration solely on verbal dialogue is especially important when English Language Learners are present. Through nonverbal activities, STEAM can provide access to topics while language skills are still developing. As such, STEAM promotes lesson differentiation and enables multiple intelligences to surface. "When students collaborate across disciplines, teachers notice when students discover something that makes their eyes sparkle. When teachers encourage that sparkle, they validate students' curiosity. That will travel with them throughout students' academic and professional careers."

One of my biggest learnings from our conversation is that in the early childhood classroom, STEAM takes many forms, from structured modeling or experimentation, to open-ended exploration. Finna teachers integrate STEAM in different ways. When Village's youngest children learn about different habitats, our students create relevant connections between that new content and their experience in our world. "A lot of what good early childhood education is, is already STEAM," explained Cynthia.

Five Strategies for Early Childhood Education Directors

1. **STEAM doesn't have to be the "cool, expensive stuff."** With tightening school budgets and frequent funding cuts, educational leaders feel pressure to obtain resources to make STEAM work. It is tempting, too, to turn to the newest technological gadgets and place them directly in the hands of students. But, Cynthia encourages other directors to reflect on necessity: "Do we really need this?," "Do you really need to pay for it?," "How exactly will we use this?" Engineering units can be taught will tubes, funnels, or pipe-cleaners. Technology is helpful in that it creates greater access to more personalized content, but at the early childhood level, to what extent do we really need tech in the everyday classroom experience? Does tech fit into the larger culture of your school, and if so, how? Piloting technology is crucial before launching a new initiative. Piloting provides a pulse on how the technology will be used in the everyday lives of its users. So many games, resources, and opportunities require nothing more than what the school already has access to. Get creative! Go to the local recycling center and ask if you can bring bags to take things. Goodwill gives teacher discounts. A little known secret is The Home Depot will let teachers take samples – for free! See if local

stores have similar deals. Take advantage of the free stuff. The free stuff is often the best stuff. Maybe this even turns into a professional development activity for teachers – to go with a group and see what you can find!

2. **Know where you are.** Zoom out, and take the big picture perspective. Before you implement a new initiative, you need to know where you currently stand. What are the areas of STEAM you want to develop further? If integrating technology is a goal, conduct some research on how this technology might be used in classrooms to support and enhance learning. Ask teachers for their input. Listen to what they say. Let teachers pilot the product. Don't immediately rush into implementing big, costly changes. Think about what you're not currently doing, so you can move forward in a way that makes sense for your students and school culture.

3. **Connect with and leverage your teacher groups.** Recognize that a lot of good early childhood teachers already do STEAM-based activities! This is part of what great teaching is! At Village, we host the Annual Texas STEAM Summit (Texas STEAM Summit, 2018). This Summit is designed to promote ways for educators to integrate STEAM in their classrooms. After the first Summit, many Finna teachers excitedly shared they were already "doing STEAM" in their lessons. The key in building a STEAM culture is giving teachers platforms through which to share their STEAM stories and showcase students' STEAM projects. Make hallways a place where student work is prominently displayed. If a unit is ending and models are no longer being used in the classroom, take those models to the hallway to showcase students' talents. Create a Facebook group where teachers can post pictures and updates for parents. This builds culture by giving parents a window into what students are learning during the school day. Also, empower teachers to form committees based on their interests. We have a Technology Committee that leads our initiatives around integrating technology in the classroom. This committee works with our IT Department and shares findings with other staff members. This is exciting because it provides opportunities for teacher leadership. We started small with this group. We are scaling as we go, based on this group's input and research. One of the initiatives this committee is working on is piloting different iPad apps. We're starting slowly – some teachers find they don't really use

the iPads. As Director, I want to give my teachers the autonomy to make those choices.

4. **Connect with and leverage your parent groups.** Recruit parents to help you collect items. Make a family event out of a walk on which parents and children can collect leaves, shells, or acorns – whatever children may find! Collecting open-ended, everyday art materials promotes more imaginative discoveries than buying a pre-constructed craft kit, with instructions and how-to guides. Letting children gather materials themselves builds curiosity. Leveraging parents to continue promoting learning during the summer is crucial. Many children will participate in summer programs. These are just one type of summer enrichment opportunity. Involve students in cooking, cleaning, playing, and exploring. At Village, we update our parent newsletter, even over the summer, with STEAM activities that can be done at home. The biggest things parents can do are to promote opportunities for children to create and engineer using everyday materials, and in ways that enable children to build ownership of a project. These materials can be found at home and outside. Let children tinker! The summer is a wonderful time to create a space in your home that is tinker space or a makerspace. Let children design their space, using their imagination. Then, this becomes their own playground, for exploration and creation driven by them. They're not opening a box, which has parts, directions, and images with a pre-set way as to how the finished product should look. Rather, they're building things from their imaginations, using materials they find and assemble. That's powerful. That's student-driven learning. That gives students ownership, and they learn to find their own solutions given available resources. Those skills will stay with children their whole lives.

5. **Understand how STEAM fits into the larger school culture and peoples' existing roles and responsibilities**. You don't want to re-invent the wheel. How can you integrate STEAM into already-existing structures so that it is more sustainable? You also don't want to be the one constantly driving the vision. If you're alone in this work, your mission will not succeed. Asking questions and involving stakeholders in the planning stages helps strengthen the integration of STEAM to build a robust and purposeful STEAM culture. You have to step back and ask: "Does this make sense in early childhood?" We also teach coding in early childhood, and that is taught in ways that are age-appropriate. Our

Technology Committee connects with our IT Department, to explore new options around teaching coding. This is not a top-down approach, it's about providing as many opportunities for teachers to be in leadership roles and advocate for what makes sense for them and their routines, classrooms, and students.

Three Ideas to Integrate STEAM in Early Childhood Education

Junk Modeling

- This is a fabulous exercise that is open-ended and provides a way for students to exercise free choice in an activity. Teachers can connect junk modeling to any theme or standard. Junk modeling does not require a lot of teacher preparation.

- For junk modeling, students bring in "junk" from their immediate environments. Maybe they stop by a nearby recycling center, a park, or a forest. Then, the teacher gives them a prompt or challenge, to which they must respond, either by themselves or as a group. Some great prompts have been designing satellites or building bridges or structures. So you might have boxes, or egg cartons, or tubes, and tape. Junk modeling engages children of all abilities, because they have a role and can work collaboratively. It engages the quiet students, as well as the verbal ones. Junk modeling is also a great activity parents can do over the summer (Pre-K4 at-home Activity).

Integration of Loose Parts

- For this activity, ask children to bring in items from their immediate environments. These could be recyclables or items from home. These items could also be something students have made in another class, such as slime (Pre-K3 Activity Slime). Then, integrate what students bring in into different lessons and areas of classroom. These artifacts become part of classroom lessons. Artifacts could be stuffed animals, toys, sticks, bark, swatches of carpet, or whatever the child finds. As the teacher and students use each item, the teacher can ask students to explain the item and how it fits into the unit, standard, or topic. Integrating the "loose part" is a great way to build engagement, direction, creativity, and problem solving skills. The "loose part" is always purposefully integrated into the lesson. This also builds in the sensory experience for students. This is a great activity for parents to do with their children (Pre-K2 at-home activity).

Coding Games

- Our approach to teaching coding has involved materials and games that do not involve technology at all. We have a robot called Cubetto, the screenless robot that helps our children learn how to code in hands-on, collaborative, and playful ways (Primo Toys, 2018). We love Cubetto because it helps our students engage with coding in a way that promotes spatial and analytical awareness. It does not rely on technology to build coding skills. There is nothing wrong with technology, but as we build curricula, we have to constantly ask ourselves: "What is the place of technology in our overall program?" To be meaningful, technology needs to be executed well, and in needs-aligned ways. The iPad will never take the place of the teacher – it supplements the teacher's skills.

A STEAM Foundation: STEAM in Elementary Education

A Conversation with Kelly Broaddus, Director of Elementary Education

"*I can't help but make progress precisely through learning by doing; every drawing one makes, every study one paints is a step. It's true that it's like going along a road, one can see the steeple in the distance, but the land undulates, so that when one thinks one is there, there's another stretch that one didn't see at first and which is added on. However, one does get nearer.*"
– Vincent Van Gogh

As I waited outside Kelly's office, I noticed a painting on one of the walls. It was of the quote, attributed to Albert Einstein: "Everybody is a genius. But if you judge a fish by its ability to climb a tree, it will live its whole life believing it is stupid." In many ways, STEAM enables all individuals to participate in an activity, contribute their skills and talents, and be assessed by their creative problem solving ability, process, and product.

For Kelly, STEAM is a cross-curricular approach to learning. STEAM threads science and mathematics into all of the other subjects. Integrating topics together in a hands-on way creates an experience for students, where they weave science into music, English, or PE. "This is learning in the most authentic way," Kelly explained. "When you break down the 'traditional' barriers among science, technology, engineering, art, and math, you show students not only that everything works together, but also that everything works ***best*** together. You create a beautiful mess, which in many ways mirrors life itself." This type of "working together" also naturally sets the stage for children to collaborate and realize that everyone brings something to the table. "Collaboration enhances the process and product. STEAM, that cross-curricular collaboration, promotes creativity and design thinking, because it lets kids explore and design."

Letting students drive their own exploration and design process also takes away the borders and barriers that adults impose. “As adults, sometimes we get very struck in the ways we think. We come up with ideas and believe that because we’ve done it this way for years, that’s the only way it can be done,” said Kelly. When adults think like this, they blind themselves to seeing new possibilities – they only see “the box” and can’t imagine thinking outside of it. One of the most exciting things for Kelly is what happens when educators promote unrestricted thinking, by taking away some of the limits and giving children opportunities to tinker, play, and create. “Children will come up with new ways to solve problems that we couldn’t even imagine. The more we provide, and celebrate, opportunities that empower children to think, the more creative they will be.” In this way, children learn, from a young age, not only to think outside the box, but also to imagine that there is no box. They have the chance to imagine the box from scratch. This gives children infinite potential to create.

“Thinking outside the box” anchored our conversation as we discussed the difference between STEM and STEAM. “For me,” said Kelly, “STEM would say: Here is a box. Find the measurements of its sides. Calculate its volume. STEAM would say: There is no box. Make one. And in this process, find the measurements of its sides. Calculate its volume.” This experiential learning process enables teachers to incorporate more standards, in more engaging ways. These processes are crucial for students to engage in early in their educational careers. Students see the benefits of collaborating, which then becomes the norm. Before designing a STEAM activity, teachers should review the standards and see how the activity promotes those standards. “In one STEAM activity, you can cover many standards. The standards aren’t taught in linearly, but non-linearly, so students see how standards relate to the issue. The learning experience will stick with students in more powerful ways.” By planning with a “backwards by design,” approach, educators ensure the STEAM experience is meaningful. “In every project you do, you’re covering Communication Standards. If students are convincing someone how to do something, they’re learning Persuasive Writing. If students are examining the history of flight, teachers can cover non-fiction literature standards,” said Kelly.

Cross-discipline collaboration also prepares students for their future. In the future, students will have to pull content knowledge from so many areas. The jobs that are focused on one domain, or require one skillset, are fading away. Students also need to recognize their strengths and growth areas – they don’t have to be good at everything, but they have to know how to get help in anything. In engineering, we need math. If we’re designing a building, we need to understand the math, or else our building is not going to function. We need that structure. And we also need beauty. We need to create spaces that people want to be in. To accomplish this, we need artists talking to architects, talking to engineers. Starting with collaborative projects in school helps make connections among these disciplines, and gets students excited about working in teams to collectively build a product. Students see the benefits of working with others. Hearing other peoples' questions can prompt other ideas: Everyone adds their ideas, and the team can build on them. That's the power of STEAM: It generates cross-disciplinary, collaborative, experiential, and student-driven approaches to learning.

Five Strategies for Elementary Education Directors

1. **Prioritize attending professional development (PD) for yourself**. It's crucial that, as directors, we prioritize time to participate in PD. Any opportunity is a great starting point. We're fortunate in that here in Houston, we have NASA, the Medical Center, the Museum District, and numerous energy, oil, and gas related companies. Many of these organizations offer PD for educators. To kick-off the year, all teachers and staff in the Elementary Division went to the Houston Museum of Natural Science. This, of course, included our STEAM Coordinator, who works with teachers to promote STEAM-based learning and is our liaison with MIT, one of our partner schools. We engaged with exhibits and watched movies on engineering. This was not only a bonding experience for our faculty, but also started the year with a shared PD grounded in STEAM. At the museum, we also played STEAM Bingo to help ground our teachers in creative approaches to STEAM. Last year, when we realized the Houston Zoo was hosting an evening event for educators, we all decided to attend. This was not only a learning opportunity, but also an event that helped create more school connectedness.

2. **Send staff to professional development.** When teachers come to you with creative ideas for lessons or their own PD, actively support them! You want teachers to find new, fresh, ideas that everyone is going to get excited about, not just students. When teachers come to me with an idea, I ask them what their plan is for executing it. What standards are they covering, and how? How are students demonstrating learning? What documentation will highlight learning and promote assessment? Promoting a STEAM culture takes collaboration and support from all individuals, at all levels. It also involves creative risk taking, which we call "failing forward." Failing forward is not blindly executing an idea, shooting in the dark, or throwing darts at a board. Failing forward is generating an idea and a tentative plan, and then executing that plan. And failing forward is crucial to learning. As a Director, I have to know what standards and essential questions are being covered. This gets teachers to think critically about their plan, and what to do if – or when –

the lesson doesn't go as planned. This helps teachers innovate and gives them autonomy and ownership. And it's ok if the lesson flops, teachers will learn from that experience. This is the balance – here is my idea and here is my plan. Try the idea and also have the plan. Be on the lookout for PD opportunities for staff, and create platforms where staff can share these ideas. Having a Facebook page is a great space to share opportunities and showcase achievement and learnings when teachers attend events. After teachers have attended PD, get creative about how to implement their new learnings into lessons. Maybe these learnings spark a collaborative project between math and English classes. Empower teachers to lead this project, then showcase student learnings with a Family Night. Invite parents, community members, and maybe even local media!

3. **Read! Read! Read! Read! Read!** Education is such an exciting field. Every day, there are new opportunities to engage with students and teachers and learn from each other. To stay current with best practices, read, read, read, read – and read some more. Read not only to stay current, but also to explore new topics. Reading helps us expand our circle of knowledge, gives us reasons to understand why we agree or disagree with ideas, and provides tools to rethink our opinions. By reading, we model that we're learners, too! When parents read, it shows children that parents are curious about the world, too. Children will naturally ask the "why" questions. Instead of answering them, turn those questions back to the children. Ask them why they think it happens. In messaging to children that their questions are important and that as parents, we are also explorers in this process, children learn the value of asking questions. Go to the library with children. Show children how to conduct a Google search. Take something as simple as mud. If you're gardening in Houston, you will hit clay. Ask children if they know why. This dialogue will drive more questions. When a child brings up the color or composition of mud, this is a great opportunity to discuss what makes mud different. And, who knows? This can lead to a conversation on different soil, architecture, design, botany, and topography.

4. **Partner with other schools, colleges and universities, community organizations and businesses.** School should not exist in a bubble. To promote and sustain "beyond the classroom" opportunities, invite local organizations to partner with your school. For example, when students

learned about architecture, we reached out to ArCH (the Architectural Center Houston), and brought a speaker in for a discussion on the art and technical sides of design. These types of activities fit very well with integrating standards-based learning (e.g. perimeter, area), as they enable students to make the connections among multiple standards and disciplines, for themselves. They also make subjects more approachable, beautiful, and "real-world," which makes the material come alive. Students also developed the story of design, which integrated language art skills. When students make these connections for themselves, learning is more meaningful and powerful. In Houston, we have the Space Center Houston, the Houston Zoo, the Museum of Natural Science, to name a few! Any city will have organizations like these, so don't be shy to reach out – they love working with schools! We also have a strong partnership with MIT, and work with them to integrate STEAM in our classroom lessons. A great example of this is when BP came to Village to host our Day of Drones and show students how they use drones in their everyday work. A lot of students thought: "This is only drones that fly." But, when BP professionals started discussing underwater drones, and how they use them to look for problems with the oilrigs in the oceans, the students loved it! Students' curiosity soared as students asked questions about problems with oilrigs and how drones operate underwater.

5. **Visit other schools**. It's so easy to become stuck in our own routines and areas – in our own box. Administrators absolutely should be out of the office, walking around hallways, engaging with students, and visiting teachers' classrooms. One particularly helpful strategy is visiting other schools, and seeing how they tackle the same challenges you're facing. Leverage your own professional networks and set up times to visit other schools. These visits provide new insights. I recently visited a school where one of the challenges was students throwing trash into the sinks. This clogged the drains and pipes, and of course had a harmful effect on the environment. Staff had to keep calling maintenance to get their trash out of the drains. The school turned this challenge into problem-based learning activity, and students were fascinated! Students drove their own learning on pipes and plumbing, water pressure, creating pipe systems, and waste removal. Students learned about the entire system of waste management. They took a hose and put it through the pipes they made, and when it came out the pipes they predicted, they cheered! Instead of saying "Don't throw trash in sinks" or giving students behavioral conse-

quences for throwing trash in the sinks, teachers turned this problem into a learning opportunity that enabled students not only to uncover the "why," but also to link multiple parts of a challenge and integrate systems thinking skills.

Three Ideas to Integrate STEAM in Elementary Education

Transportation Unit

- As part of our kindergarten curriculum, we do a transportation unit. For this unit, our teachers engaged our bus driver. Students got on the bus, and our Assistant Director dressed up as Ms. Frizzle, as though she were taking students on a trip. We asked questions such as: "What's the best way to get from here to there?" and "If there were no limits on the science of engineering a vehicle, how could we do transport people?" So students made vehicles of the future, from ones that could travel underwater, to having hot air balloons that flew over traffic. As students created these vehicles, they discussed safety – why seat belts, stop signs, and red lights are important, why we turn a certain way. This integrated Social Studies standards, and the history of transportation, engineering, and design. Our MIT lead helped us examine the design of paper airplane – how it has changed over the years – and how that design effects how far and how fast the airplane goes. Students brought in fans to simulate wind. The whole process was trial and error, failing forward, and exploration. Students learned so many concepts: They could see how a simple bend of the airplane, or tweak in the nose, or weight on the wings, affected the airplane's flight path.

Pendulum Paintings

- Our second graders have art, and our art teacher always brings professional artists into the classroom. When artists come in, they always discuss their methods and their inspirations. Our most recent artist talked about how she incorporates movement into her art. She asked our second graders if they knew how motion affects art. This turned into our students' Pendulum Paintings. For this project, the artist started by asking students to fill a water bottle with paint and hang in from a structure, which students made. Then, students tested what happens to the amount of paint released when they changed the weight on the string, the size of the hole in the bottle, and the rate at which they swung the bottle. The students discovered that if they swung the bottle faster, it made thinner paint lines, and if they swung the bottle more slowly, it made thicker lines. In this hands-on process, our students got messy (they had to wear trash bags over their clothes). And they loved it! They learned how art and physics combine to create beautiful pendulum paintings (see Figure 2).

Figure 2 *Pendulum Paintings.* Second Graders connected physics and art to make pendulum paintings. They built a scaffold and hung a water bottle full of paint from the scaffold. They learned how changing the speed and size of the hole change the paint streams generated.

Ozobots and Habitats

- Our third graders do a unit on habitat. Part of the assignment is to show how an animal navigates through its habitat. To do this, students leveraged technology by using mini robots called Ozobots. To move, the

Ozobots follow the path of a marker. So, students took markers and drew patterns for the Ozobot to follow. The Ozobot could turn around, stop, turn right, left, reverse, or skip over something. So, for their habitat projects, students created a little animal and put it on top of the Ozobot. Then, students drew patterns through the habitat for the Ozobot to follow. Students showed their animal running from predators, or turning around to get water, or going into a little cave to rest. This activity not only showed everything students learned about their habitat, but also enabled teachers to cover all of their science standards. Integrating the Ozobots also taught students how to apply authentic coding skills to their habitat. In this project, technology was a very powerful tool that aided learning in a very purposeful way.

A STEAM Foundation: STEAM in Middle School Education

A Conversation with Cindy Proske, Director of Middle School

"We are born makers. We move what we're learning from our heads through our hearts to our hands."
– Brene Brown, *Rising Strong*

Cindy's office is always buzzing with inquisitive students or teachers eager to brainstorm ideas with Cindy. Cindy's welcoming and warm personality set the tone for our conversation. It was abundantly clear that Cindy has a passion for Middle School education, and a vision for executing that passion by empowering her teachers and staff.

For Cindy, the STEAM framework provides a "sandbox-like" environment for every class, in which students are free to use the resources around them to tinker. "We were doing STEAM long before we knew what it was and we put a name to it," said Cindy. "We were integrating core classes together and developing projects with cross-curricular components. I think this is the case with a lot of schools: teachers are already 'doing STEAM' without necessarily labeling it as such." The Village Middle School curriculum already integrates math and science in other disciplines, since this creates a more purposeful learning experience and builds skills in all subject areas.

The "STEAM as sandbox" analogy helps Cindy understand how STEAM creates opportunities for collaboration. When working together, the most confident students take creative risks earlier in the process. But then, as Cindy explains, they will also teach others, so students encourage and lead each other. This is precisely the learning environment educators love. One example of this is when a more confident Middle School student taught another student how to build a robot for Village's fashion show. That's

STEAM powering collaboration and cross-curricular skill building. When one student takes the first creative risk, others follow. This mindset develops into a growth mindset as students move through Middle School to High School. “These are the students who we see rise to the top of their class – the students who know how to take the creative risks and who view failure as feedback, rather than final.”

In Middle School, there are so many ways for teachers to model creativity and weave it into lessons. One of these ways is in Language Arts class. Students read a book about seedlings. One of their assignments was to grow plants in the hallways and off the walls. For this assignment, students not only became producers of knowledge, but also cultivators of a product that they had grown. They did not just present a poster, and then move on, but rather grew plants to show their learnings – which integrated Language Arts, science, and math skills.

Another fabulous example of STEAM in action is from a Middle School history classroom. Cindy explained that students were studying Westward Expansion. Their teacher gave them the assignment of making a “How to Get to the West for Dummies” book. The students were responsible for writing the book, advertising it, and researching facts to support their book. This project gave every student a chance to participate, contribute, and learn – and to take pride in a product they had produced. This project also gave students autonomy to create their own experience as they collaborated.

Another example is from math. When Middle School teachers cover probability, some of the assignments are to make math-based games. Students spend time collaborating to make and test these games. Grading is based on how well students plan the activity and whether students have a workable hypothesis grounded in the math concepts they have learned. At the end of the unit, teachers set up a Carnival with students’ games. The process of planning, generating a hypothesis, working together, and then playing the game itself are all important. For Cindy, “This is problem-based learning, at its best.”

At Village, we have a greenhouse with a hydroponic tower. When we tour teacher candidates, we always take them by the greenhouse. On his tour, one teacher saw the greenhouse and started discussing his work with a robot that measures pressure and temperature inside the greenhouse. So, now, Village is hiring teachers who think outside the box, as well. Bringing in more teachers who are familiar with STEAM strengthens Village’s STEAM culture. Current teachers feel supported, empowered, and a part of this STEAM culture. Without teacher buy-in, building and sustaining a STEAM culture will never happen. A large part of our job, as directors, is supporting teachers by asking questions such as “How can I help you make STEAM work in your lessons?,” and listening to what teachers say. Match new teachers with teachers already doing STEAM. These teachers already have effective processes and scaffolds for integrating STEAM. These processes and scaffolds also help measure and evaluate how STEAM impacts learning.

To create a STEAM culture, having parents onboard is crucial. Of course, parents want their children to be successful. "As we integrate STEAM, we have to remember that STEAM wasn't a thing for parents." To help parents understand STEAM, Cindy plans to bring back former Middle School students to discuss their experiences with current students and parents. "Middle School is a time of exploration, of failing forward. Middle School is when we spend a lot of time teaching our students how to grow as human beings," said Cindy. When students have a space such as a makerspace, where they can go to collaborate and tinker, they realize the value of exploration, making mistakes, and failing forward as they grow and collaborate. This mindset helps students develop confidence and learn from failure. These skills position students to be more innovative and curious as they graduate to high school, head to college, and start their careers.

Five Strategies for Middle School Directors

1. **Find your early adopters.** In any organization, there are always individuals who are eager to try new initiatives. They will be onboard, help manage resources, and be creative with resources. A key strategy as directors is to leverage your relationships with teachers, staff, and students to identify and onboard individuals who are early adopters. These individuals will pilot initiatives and give feedback. These individuals, especially students, will become change leaders and will empower each other to sustain the initiative. The students will be very engaged, because their friends are. Once other teachers see this engagement, they will want to come onboard, too.

2. **Train, train, train. Support, support, support.** Sustaining ideas takes ongoing training and support. Having the initial meetings are great, but what happens after those? As directors, we need to be thinking of closing the loop – from start, to, and through finish. We are always asking: "What happens next?" What personalized training, readings, professional development (PD) can we offer one, two, three months, after an initial event? Providing opportunities for teachers to share and showcase their and their students' learnings helps sustain a STEAM culture. Ongoing training and support give teachers the knowledge and skills to continuously apply their learnings. When teachers choose their own PD, they link their interests with their own professional growth and learning.

3. **Trust your team, without micromanaging them.** Very few people like to be asked to complete a task without having general guidelines and some scaffolds. As directors, provide the guidelines and scaffolds. These create clear expectations for success and a path to help teachers get there. But, provide these guidelines and scaffolds without micromanagement. Teachers, especially when implementing new initiatives, need support, space, and freedom to try. In the process of trying, failure will happen. The lesson and activities won't go as planned. When that happens, use failure as an opportunity for learning and reflection. Then, give teachers a chance to apply what they've learned.

4. **Celebrate the successes!** Encouraging teachers and highlighting their work in meetings, screencasts, or announcements to other teachers, or through emails to parents, or during lunchtime with students demonstrate appreciation for work done well. Celebrating the successes not only gives teachers compliments and builds a culture of appreciation, but it also highlights successes so that others want to be onboard. Make it a point to find meaningful ways in your school culture to celebrate teachers' successes.

5. **Find a way to make ideas a reality.** When teachers, staff, or parents approach you with an idea, if that idea fits in with the overall vision, find a way to make it happen. Ask for donations from corporations, parents, or local businesses. Look for space in your budget. Support teachers from the moment they approach you with a plan, to make their vision a reality. Help teachers find trainings or conferences. You can have internal meetings and planning sessions all day long. But, when teachers go out and hear other individuals having similar discussions, that validates the work you seek to do.

Three Ideas to Integrate STEAM in Middle School

Future City

- Our of our students' favorite projects is in Science class. For Future City, students ask: "What will Houston look like in 50-100 years?" This leads to more questions, such as "How can the community function as a whole?," "What does transportation look like?," "How do we grow food?," and "How do we care for all individuals – from the newborns to parents, to older citizens?" Students develop blueprints for what our city might look like, complete with technology and transportation. Many students think of a city on the ocean, which prompts them to ask: "What happens when a tsunami hits?" Students also imagine a double-layer, self-sufficient, and "green" city, with walking paths that generate energy. This is a great project to do in whatever city you're in. It invites students to look ahead and connect the past, to the present, to the future, and to showcase these learnings. In this process, students create a city through the lens of science, technology, engineering, art, and math. Students see themselves in this process, as not just participants in, but also creators of, their futures.

Media Center/Makerspace/Tinker Space

- Our media center is an open space. In this space, we have laser cutters, coloring books, and sewing machines to name a few things. Language Arts uses this space a lot! In this space, students activate their imagination to choose what tools to engage with and how they want to engage with these tools. We even build wellness into the activities – coloring books bring in mindfulness and enable students to monitor and regulate their own emotions. We make games in this space too. This unstructured space is crucial for student-drive exploration and provides a place where different skills come together. The media center enables STEAM to come alive, since students not only think in terms of more possibilities, but also work side-by-side on different projects. Maybe they decide to make a video, which could be something they have never thought of. Students learn to use phones and technology in new ways. In this space, students have the freedom to create, using the materials in their immediate environment. Students drive their own creative process to design their own product. Students even made a tool holder, using the 3D printer (see figure 3). Students can come in at lunch, on their own time, and tinker, experiment, fail, and try again. Other students see them and encourage them by saying: "Keep trying." This attitude motivates students to want to explore more.

Figure 3 *Makerspace Designed, 3D Printed Knife Holder.* In their makerspace, students designed and 3D-printed a holder for the tools they use. They recognized the need to store their tools safely, so they made a holder.

ExploraVision

- ExploraVision (ExploraVision, n.d.) is a Toshiba-based competition where students dream up a new idea or innovate an existing one. The competition is student-driven: Students have to do the research and they have to develop their ideas. Throughout the process, they work with teachers who mentor them. Village had four sixth-graders who won second place in the nation. These students' idea was to research animals that regenerate themselves. They settled on the crayfish and came up with a plan to extract the regenerative cells from crayfish and inject them in people who are paralyzed. Students designed websites, wrote the research paper, and were invested in their learning experience. STEAM makes the learning very personal: Students link their own motivations and interests to academic settings and take pride in a product they create.

A STEAM Foundation: STEAM in High School Education

A Conversation with Carl Newman, Director of High School

"It needs time. Nobody wants to hear it, but that's the truth: If you want to have success in the future, you have to be read to work now."
– Jürgen Klopp

As I waited for our conversation to begin, Carl was chatting about soccer (or as Carl, who hails from the UK, corrects me, "It's football!") with one of our students. From listening to their conversation, it is clear that Carl is not only knowledgeable about soccer, but also passionate about engaging students as holistic individuals, with interests beyond the classroom.

For Carl, STEAM is a way of thinking that identifies and analyzes the overlaps and connections among disciplines. Carl has never taught science, technology, engineering, arts, or math – he has taught history. "History is a subject that is the best example of how STEAM is interdisciplinary – yet I don't see the 'H' in STEAM," Carl chuckled. For Carl, history discusses all subjects – science, the development of technology, engineering, art, math, psychology, literature, and economics – through the lens of the human experience. Adding this lens enables students to make connections among disparate subjects and contextualize events. This lens invites students to ask – and answer – the "why" questions.

The "A" in STEAM captures the human experience and places it with the sciences. To truly understand the importance of Galileo's contributions to science, we also must understand the Catholic Church. To truly understand medicine, we also must understand the history of science and perspectives on the human body. One of Carl's favorite classes to teach was the History of Medicine. In this course, Carl covered topics in medicine from the Egyptians to modern day. One of the essential questions was "What influences thinking about the body?" To help support students' responses, Carl bridged science, history, physiology, infectious disease, and surgery to show how these different disciplines impacted the body. The course also examined medicine through the lens of religion, and not just the lens of a microscope, because religion shaped how people understood what happened to their bodies.

As educational leaders who believe character education is important to being empathetic citizens and innovators, our goal is to include the human element in everything we do. Art and history are ways of understanding the human experience. Art is an expression of the human experience. "Adding art brings the human element into science, and this I always felt was missing from STEM," said Carl. "To understand the systems in STEM, we must understand the humans driving the systems. We need to understand how humans think, share experiences, and make decisions and connections. When we share experiences, we're doing STEAM." For Carl, STEAM is a gateway to promoting "habits of mind" or the mental models that inform how we engage with information. An example Carl shared to illustrate "habits of mind" was watching the news. When we watch the news, do we automatically agree with everything presented to us? Or, do we view the news with a healthy dose of skepticism, and compare how each item we see squares away with our own understandings of different disciplines?

In this way, STEAM becomes an integrated way of asking and answering "How do we know what we know?" If, when we answer, we consider only one discipline (e.g. without a STEAM perspective), we get a limited answer – an answer that only looks through one lens. When we ask this question and consider all disciplines (e.g. with a STEAM perspective), we get a robust answer that presents a more complete picture. As humans, we tend to overemphasize a rational thought process. But in this process, we sometimes forget that experiences can be, and often times are, more powerful than simply memorizing or recalling facts. STEAM helps us create these experiences by bringing in stories, enabling opportunities to go to places such as museums or out in the field, and make products to showcase learnings.

The ability to create these experiences is essential to building a STEAM culture. A large part of building this culture is remembering that STEAM looks different in every classroom. "We have to ask ourselves, 'What does creativity look like in a math classroom? What does creativity look like in every classroom?,'" said Carl. Creativity in the classroom involves teachers: How is their lesson plan creative? Are their instructional methods creative? Are their word problems creative? Creativity in a math classroom also involves students. Creativity could be in the problem-solving process – how students actually approach and solve the math problems. Students might have a starting point – variables, numbers, or an equation, and they have to come up with an answer. In an art room, creativity is a bit more easily recognizable. In both disciplines, students and teachers must have a certain level of content knowledge before they integrate problem-based learning. Whereas in history, being creative and integrating STEAM might look more like taking on different perspectives, and thinking about an issue from those perspectives. The facts might say: "The colonists arrived in the 17th century." When we start collecting all perspectives, from the colonists' and natives' point of view, and compare those perspectives, what do we see? We see the whole picture.

STEAM provides the whole picture. Having the whole picture helps individuals stay informed as critical, analytical, and conscious thinkers. And, with this picture, we don't just accept an answer at face value. We go deeper. We not only keep asking "why," but also seek to understand the issue from multiple perspectives. This skill is especially important in the 21st century. It seems like everyone has an opinion, and everyone wants to have a say, and as critical thinkers, it is our job to ask ourselves, "What disciplines inform that opinion?" and "How is that person obtaining their facts and connecting their thoughts?"

Five Strategies for High School Directors

1. **Agree on core principles to apply in classroom**. Before going full STEAM ahead, reflect on what it means to be a STEAM school. What are students and teachers doing on an everyday basis to take a STEAM approach to their learning? Sit down with your Department Heads and get their input. Generating core principles helps solidify what STEAM looks like and gives teachers guidelines to provide the foundation for lessons. It also helps to build-in from all teachers and staff, because agreeing on core principles prompts conversations on what faculty can do in their existing roles, with their existing skills, to promote STEAM. Core principles give teachers guidelines, without limiting their own creativity. Too many principles can confine creativity. These core principles are like roots: Every tree has roots. But, not every tree looks the same, or has the same branches and leaves. These principles cultivate creative habits of mind in teachers, enabling them to cultivate creative habits of mind in students. What are the core activities that promote these habits of mind and principles?

2. **Create a teacher evaluation system that promotes awareness and growth.** We do informal walk-throughs and formal evaluations at Village. It is critical that when, as directors, we evaluate teachers, we do not judge teachers on a skill or habit that is outside of their awareness. If teachers do not know they should be doing something, how is evaluating them on that skill fair? When we evaluate teachers, we want to grow their skills and ensure they have access to relevant and ongoing professional development. We started a teacher mentoring program to ensure these scaffolds are in place and accessible to teachings on a continued basis. Our faculty member who leads this program works closely with

our newest teachers. One of the scaffolds we have in place with this program is that she does not have to report who she is coaching and for what, to me. She doesn't mention names and this helps teachers actually grow and develop their skills without fear.

3. **Leverage community organizations for partnerships and support.** When building a STEAM culture, recreating the wheel is not necessary. If you find a community group already working with character building or teacher training for example, bring them in to facilitate a teacher training. If there are specific educational technology tools that might be helpful, see if the company will run a pilot at your school. In this way, technology is integrated into your school culture, without it being randomly brought in just because it is the newest technology. Building relationships with community members is an excellent place were as directors, we can encourage teachers to develop the habits of mind to say "What community resources can I bring into my classroom and how will that purposefully support students an sustain learning?"

4. **Reflect on your own understanding and practice of leadership.** "This was my first full year in my role as Director of High School," explained Carl. "I learned a lot, and that is an understatement." This learning process helped Carl reflect on and identify his goals for next year. "There's so much I want to do next year. I want to involve students more and let students design more processes and systems." One issue in particular is litter left in common areas on campus. In reflecting on his own leadership style and practice, Carl thought of ways to involve students more in creating solutions to challenges. "When students come up with solutions themselves, the behavioral management system is much more collaborative, sustainable, and powerful." Something Carl saw at Texas A&M has stuck with him. At Texas A&M, no one walks on the grass. If visitors try to, a Texas A&M student will tell them, gently, but strongly, not to walk on the grass. Students police themselves. Carl wants to build more of that culture at Village. The starting place, for Carl, has been reflecting on how he leads. "I am looking forward to using the summer to reflect and take stock of the past year. The summer is a great time to do this," said Carl.

5. **Don't be afraid to try new things.** Directors have access to resources that support teachers and students. Directors can make choices to pro-

mote and support STEAM in the classroom. Don't be afraid to try new things, especially when teachers come to you with a plan. Provide constructive feedback and help teachers execute their vision. Also, get student buy-in when you can. Start with piloting an initiative on a small scale, and seeing what students think. Have multiple avenues for feedback: Google Forms, a suggestion box, office hours, and student-run Town Halls that are open to faculty, staff, and students. Work with your Student Council to listen to their concerns and together, construct a plan. Revisit the plan as you execute it. Have frequent checkpoints that ensure communication is open and meaningful.

Three Ideas to Integrate STEAM in High School
Civilization Project

- One of the projects in our Social Sciences classes examines civilizations. In this project, students design their own civilizations, based on the previous ones they have studied. Students take an interdisciplinary approach by building real-life models and looking at the scientific development of a civilization. These models have to be visually appealing and constructed to scale. When students display and discuss these models, they develop confidence in sharing the process behind the development of their product. These projects create ongoing dialogue on the importance of architecture, engineering, and the values and history of a civilization.

Pumps and Pipes

- Pumps and Pipes is Village's summer STEAM Academy. It is a four-week summer program designed for high school students. Students engage in problem-based and place-based learning experiences and create solutions for real-world challenges. As part of their summer experience, students visit NASA, ExxonMobil, Houston Methodist, and University of Houston, where they collaborate with Aerospace, Energy and Medical professionals (The Pumps and Pipes Summer STEAM Academy, 2018). Pumps and Pipes culminates with students working in groups on a Capstone Project.

Displaying and Celebrating Art

- At Village, we display and celebrate student art anywhere we can! Our hallways are lined with student art, which is a wonderful way to put STEAM on display for parents, teachers, staff, and visitors. We also host our IB Art show, in April. This event showcases art from students' portfolios. There is a story behind each piece of art. When the students tell the story of their art, they give voice to STEAM as a process. Students make the connections from the technique and style to the story. There is variety and the art pushes boundaries. Each piece of art engages the viewers and makes them think more deeply about their own human experience. This process takes viewers beyond the surface level experience and invites them to connect their own experience to others' experience.

A STEAM Foundation: STEAM & Entrepreneurship Education

Reflections from Christine Galib, Director of Entrepreneurship & Wellness Programs

"There is no spoon."
– The Matrix

One of my all-time favorite movies is *The Matrix*. Every few years, when I re-watch it, I notice more and more ways in which science, technology, engineering, arts, math, philosophy, and ethics intertwine to illuminate humans' relationship with machines, technology, and ultimately, with each other. For me, *The Matrix* is a fabulous example of STEAM: It integrates science, technology, engineering, art, and math in ways that inspire us to curiously question our reality and to identify, appreciate, and celebrate our humanity.

For me, adding art is crucial. Without the arts, STEAM is just a STEM: a long stalk, and not the whole flower. Adding the "A" for art gives the whole, beautiful, and functional flower. STEAM enables integrated thinking and problem solving from multiple, cross-disciplinary perspectives. The scientist sees what the technologist doesn't necessarily see, the engineer brings mathematics to life and application, and the mathematician analyzes a problem in ways the artist does not. Individuals observe the problem through their own unique filters. These filters are created by each individual's expertise and experiences. When each person adds these filters and perspectives to designing a solution, that solution is more robust and sustainable.

Sometimes, I like to think that the "E" in the STEAM is for entrepreneurship, since I find STEAM and entrepreneurship to be very much related. Entrepreneurs design-think solutions that solve our and users' problems, by considering all users' perspectives, from prototyping to production. To do this, we not only consider what works for us, but also, and more importantly, what works for others. We apply our own problem solving skills to creating a product that meets the needs of others. One of the tools that helps us uncover and examine others' perspectives, and observe them in non-judgmental ways, is mindfulness. Mindfulness is purposefully and non-judgmentally paying attention in the present moment (Kabat-Zinn, 2013). Mindfulness helps individuals see how to explore, experiment, fail, and fix – a process STEAM, as a way of thinking, promotes (see Figure 4).

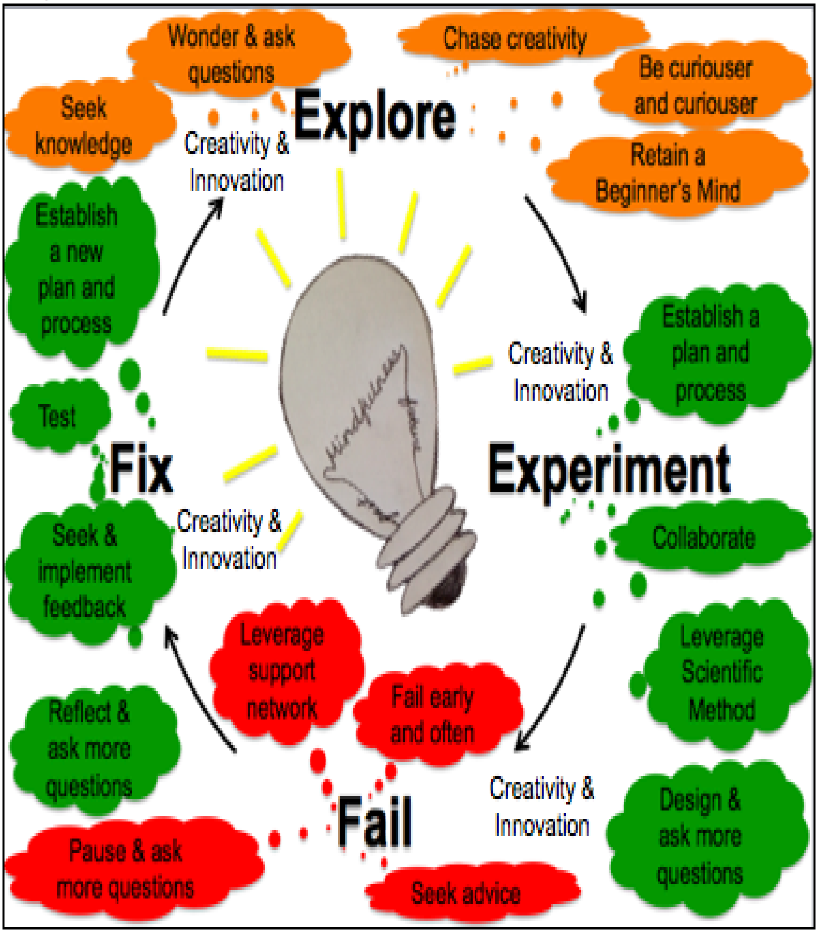

Figure 4 *Explore, Experiment, Fail, Fix.* Mindfulness links our past to our future. It enables as to see how to apply STEAM-thinking and iterate in an "explore, experiment, fail, and fix" process. Creativity and innovation drive this process forward. "Mindfulness as Lightbulb" reprinted from Galib (2017).

Creativity and innovation drive this process. In doing so, mindfulness links our past to our future. Through better positioning us to explore, experiment, fail, and fix, mindfulness helps us see how STEAM facilitates design-thinking and creates a future that is not just different, but better (Thiel, 2015).

Full STEAM Ahead: Cultivating the Lifelong Learner and the Curious Mind

"Creativity is allowing oneself to make mistakes. Art is knowing which ones to keep."
– Scott Adams, *The Dilbert Principal*

Full STEAM ahead, but to where? "Ultimately, STEAM is people-centric, not subject-centric; it puts student personality and individuality at the forefront" (Feldman, 2015, para. 13). When we promote personality and individuality, we empower students to link their personal interests to their educational process. School becomes more purposeful, since learning is more personalized.

According to Gabriella Rowe, Head of School at Village, "STEAM is incredibly important, for the overall development of children." STEAM enhances the learning and development of children, since it is interdisciplinary. "A learner doesn't walk into science class and open the 'science part' of their brain, and then when the learner walks out, they shut that part and open another part of their brain when they enter another class." This is not how education works. For Rowe, education should be holistic and not fragmented – something education has been for many decades. "Education should not be fragmented. We are teaching to the whole child," said Rowe. For many students, it can be difficult to "flip a switch" and integrate these historically siloed subjects on their own. Education must be interdisciplinary, so that when students leave school, they "can access these different pools of knowledge," said Rowe. "STEAM provides wonderful opportunities for educational leaders to make interdisciplinary learning a way of life and an educational culture with connected learning at its core," said Rowe.

With STEAM, the possibilities are endless. "With STEAM, the pressure is off to become a scientist or engineer—you can be a designer, digital artist, coder, art director, and scientist and engineer all at the same time" (Feldman, 2015, para. 13). STEAM changes the question from "What do you want to be when you grow up?" to "What problems do you want to solve now, what resources and skills do you need to solve them, and who can help you solve them?" Reframing the question in this way gives "children strategic opportunities to make connections in ways that they would not otherwise have made if they were taught in individual strands or silos," said Rowe. For Rowe, STEAM changes students' mindsets in a "way that is authentic and does not feel manufactured or staged." Students become creative and innovative problem solvers, connecting cross-disciplinary content to find solutions.

This is exactly what the "real world" is like: "In the real world, we integrate science, technology, arts, and engineering. And, math is part of everything," said Rowe. As humans, we problem solve integratively and consider multiple angles to arrive at a solution. This is as "real world" as it gets, especially given the changing nature of work. "There are very few jobs, probably shifting to none very quickly, in today's world or our children's future world, that are mechanical and rote. We have artificial intelligence and robots that do those jobs for us." This changing work landscape has disrupted systems and processes, resulting in digitalized, automated methodologies for completing what once were manual, routine tasks.

For Rowe, this means humans must have "high levels of creative problem solving skills, high levels of interdisciplinary thought, and a whole lot of flexibility and resilience." STEAM positions students to develop these skills now, so that students are prepared for their future. "We talk a lot about the jobs of the future that haven't been invented yet. But, we don't talk a lot about the jobs that will be gone – or the categories of jobs that will be gone," said Rowe. "Jobs that require routine thinking, processing, automated calculations, tabulation of information, entry of information, routine tasks of any kind, are already vaporizing. Even something as simple as a call center will no longer be necessary." Machine learning and artificial intelligence systems have the capability to comb through data and produce answers for callers. This does not require human beings. The jobs that do require humans are the jobs that create and manage these systems. "The person who figures out how to develop that methodology and mount these platforms, will be a human. Will they be trained to do it? Not without STEAM, they won't," said Rowe.

By creating a culture of STEAM in our schools, we, as educational leaders, empower students to think differently by inviting them to link their own experiences and interests to making connections among data and information across different fields. Facility with seeing themes and connecting information across disciplines better prepares students to think more curiously, creatively, collaboratively, and compassionately. Students learn not only to cross-pollinate information from one subject to another, but also to work in teams and consider the perspectives of others in nonjudgmental, empathic ways, as these perspectives relate to solving an overall problem solutions that are more sustainable and purposeful. In this way, STEAM brings individuals together, helps uncover blind spots in one individual's thinking process by illuminating and incorporating multiple perspectives, and leads to more inclusive solutions that are authentically design-thought to meet the needs of all users.

This chapter has presented conversations with our Directors, which illustrate how Village implements a culture of STEAM. Our youngest students explore their curiosity and engage in interdisciplinary learning that challenges them to think, puzzle, and explore in hands-on, verbal and nonverbal, and experiential ways. Our Elementary curricula build on these themes, by offering more opportunities for students to drive their own exploration, learning, and design process – thinking outside the box and integrating information from multiple fields to collectively create airplanes, habitats, or paintings. In doing so, students create projects and products that are not only useful, but also beautiful. Our Middle School students have ample, avaialble, and accessible opportunities, from the classroom – with lessons that extend readings by integrating gardening – to outside the classroom – with Makerspaces that provide unstructured time to tinker and build – to drive their own education in ways that integrate their school subjects. Our High School students learn that it is not enough to discuss creativity in the classroom. Rather, they learn that identifying how creativity looks different and functions differently in different classrooms is the first step to identifying creativity in our world. Identifying creativity in our world helps students identify and execute their own creativity.

Empowering all stakeholders – not only students, but also, and especially, teachers and parents – is crucial in creating a sustainable STEAM culture. Providing feedback, opening constructive dialogue around failure and the importance of life-long learning, and providing opportunities to learn from and showcase and apply learnings from professional development are foundational to empowering teachers with tools to build a culture of STEAM. As leaders, we set the tone for this culture – by encouraging exploration and "failing forward" and by modeling curiosity, creativity, collaboration, and compassion. First, we must develop and promote these skills ourselves. So, full STEAM ahead, to a future that is more collaborative, creative, sustainable, and not just different, but better (Thiel, 2015).

References

Berridge, E. (2017, December). *Why tech needs the humanities.* Retrieved from https://www.ted.com/talks/eric_berridge_ why_tech_needs _the_humanities?

ExploraVision (n.d.). *ExploraVision.* Retrieved from https:// www.exploravision.org

Feldman, A. (2015). *STEAM rising: Why we need to put the arts into STEM education.* Retrieved from http://www.slate.com/articles/technology/ future_tense/2015/06/ steam_vs_stem_why_we_need_to_put_the_arts_into_stem_educatio n.html

Galib, C. (2017). Being in the present to create the future: Mindfulness as a key for unlocking our creative potential. In F. Reisman (Ed.)*, Creativity, Innovation and Wellbeing.* London: KIE Conference Publications. Retrieved from: http://www.conference.kiecon.org/ publications/

Isaacson, W. (2017, October 1). What Steve Jobs had in common with Da Vinci. *Vanity Fair*. Retrieved from https://www.vanityfair.com/ news/2017/10/new-establishment-innovators-connection

Kabat-Zinn, J. (2013). *Full catastrophe living: Using the wisdom of your body and mind to face stress, pain, and illness.* (Revised edition). New York, NY: Bantam Books.

Kennedy, B., Hefferon, M., and Funk, C. (2018, January 17). *Half of Americans think young people don't pursue STEM because it is too hard.* Retrieved from http://www.pewresearch.org/fact-tank/2018/01/17/ half-of-americans-think-young-people-dont-pursue-stem-because-it-is-too-hard/

Lynch, M. (2018, April 6). *Why does arts integration work?* Retrieved from http://www.theedadvocate.org/why-does-arts-integration-work/

Pre-K2 at-home activity. (2018). *Pre-K2 at-home activity*. Retrieved from https://www.facebook.com/notes/the-village-school/pre-k2-at-home activity/10156206077454884/

Pre-K3 Activity Slime. (2018). *Pre-K3 Activity Slime*. Retrieved from https://facebook.com/notes/the-village-school/pre-k3-activity-slime/10156232290749884/

Pre-K4 at-home Activity. (2018). *The joy of junk modeling*. Retrieved from https://facebook.com/notes/the-village-school/pre-k4-at-home-activity/10156232196449884/

Primo Toys. (2018). Cubetto. Retrieved from https://www.primotoys.com

Rowe, G. (2017, July 31). *STEAM learning at home*. Retrieved from https://www.houstonfamilymagazine.com/education/steam-learning-home/

Senge, P., Smith, B., Kruschwitz, N., Laur, J., & Schley, S. (2010). *The necessary revolution*. New York, NY: Crown Business.

Texas STEAM Summit. (2018). *Texas STEAM Summit*. Retrieved from https://sites.google.com/thevillageschool.com/steam-summit/home

The Pumps and Pipes Summer STEAM Academy. (2018). *The Pumps and Pipes Summer STEAM Academy*. Retrieved from https://www.nordangliaeducation.com/our-schools/houston/village-school/student-life/summer-programs/the-pumps-and-pipes-summer-steam-academy

Thiel, P. (2015). *Zero to one: Notes on startups, or how to build the future (Paperback Edition)*. London, UK: Virgin Books.

U.S. Department of Education. (n.d.). *Science, Technology, Engineering and Math.* Retrieved from https://www.ed.gov/stem

CHAPTER THREE

ENGINEERING CREATIVITY: EXPLORING DISCIPLINARY DIFFERENCE AS THE BASIS FOR NEW PEDAGOGICAL IDEAS

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Abstract

This chapter explores the distinctive and often contrasting educational approaches associated with engineering and musical disciplines. Both inherently 'practical' subjects with a rich body of underlying 'technical' knowledge and rich historical heritage, convention nevertheless determines often highly contrasting educational approaches to their study and fundamentally different conceptions of subject identity. Acknowledging a shared focus on the value of creativity, this chapter interrogates the notional differences in pedagogy between the two disciplines—their subject traditions—and considers the extent to which particular experiences of subject consequently inform future behavioural attitudes and the realization of creative potential. Exploring how music and engineering reflect very different schemas, the chapter considers how cross-fertilization between subjects might frame different conceptions of creativity and inform alternative educational strategies. Noting, for example, the concept of 'proactive interference' and the potential for cognitive inflexibility through mastery and expertise, the chapter explores how a more musical approach to the study of engineering could inform the more effective development of creative engineers.

"Engineers should embrace the arts as being key to creativity and an important component of innovation, crucial to creating new products and boosting future competitiveness."
Sir John O'Reilly (2014)

Introduction

This chapter is focused on engineering education and particularly on higher education and the development of creativity. Drawing from experience of working in the UK higher education sector, and in a particular from insights gained through working across a wide range of subjects and departments, and consequent appreciation of variations in educational approaches and learning cultures ranging from the subtle to the profound, the differences between pedagogical approaches are explored for their potential to inform new ideas.

Acknowledging the etymology of engineer, from the Latin *ingenium* and medieval Latin *ingeniator,* the word, whilst grounded in concepts of creation and making, also reflects historical diversification and increasing complexity and specialisation; an evolution from discipline to a dynamic sphere of micro-disciplines. From middle English craft and design associations with construction, the term now encompasses a vast array of highly specialised and dynamic areas of expertise of increasing, even critical, importance to all areas of human society. Broadly categorised as mechanical, chemical, civil, electrical and geotechnical (National Academy of Engineering, 2004), engineering, like many subjects was once quite easily defined but now encompasses extraordinary breadth and diversity.

Whilst inherently creative as a discipline, Stanford University professor of engineering James Plummer's call for "a new breed of engineer" (Perry, 2017) at the IEEE (Institute of Electrical and Electronics Engineers) Vision, Innovation and Challenges Summit in San Francisco is reflective of wider advocacy of the need for engineers of the future to be capable of operating in very different ways in order to successfully navigate both very different careers and very different engineering challenges. Reflecting a shift in focus towards the development of higher level skills more closely aligned to creativity and innovation in order to successfully do "what technology cannot do", Petty in Smith (1991) identifies a number of factors driving a need to reconsider educational approaches to engineering, including internationalisation, automation, an increasing pace of redundancy of knowledge requiring retraining and ongoing education, and the emergence of new fields of expertise and application.

Recognising a paradox in increasing scale and interconnectivity, whilst innovation seemingly occurs best through individuals in entrepreneurial settings (Chu, Et. al, 2004), calls are widespread for educational approaches for mobility (geographic and cultural), increased focus on creativity, entrepreneurship and enterprise (Badran, 2007) and for greater awareness of the social dimension of engineering. The focus in engineering education has been shifting for several decades away from knowledge and skills—via "quill pen and Slide Rule (Plumbridge in Smith, 1991: 19)—and towards "personal and attitudinal development".

Given that the future needs of society are widely held to be different, even profoundly different, from those of previous generations, there is corresponding and consequent projected need for greater creative human capacity and increased value being placed on creative ability (World Economic Forum, 2016). Whilst the global focus on access to education remains perhaps the most pressing concern, there is in addition a growing focus on reshaping the aims and outcomes of educational systems more generally and that a longstanding "production of cogs for an unchanging industrial or bureaucratic machine must no longer be the prime concern" (Petty in Smith, 1991: 9). Furthermore, it is not just that engineers of the future will require different skill-sets, the supply of necessary expertise is also an increasing concern. From surveys of the manufacturing sector in the UK indicating 67% voicing concerns of future skills shortages (The Engineer, 2017), to Engineering UK's report indicating a twenty thousand per annum shortfall of engineering graduates in the UK alone (Engineering UK, 2017), the skills-gap has been identified as an "insidious threat" to the engineering sector resulting from "a chronic failure" to effectively engage young people with engineering study at higher levels of education (Royal Academy of Engineering, 2016). In addition, the increasing significance associated with technological literacy across all subjects has led to more general calls for the urgent need to develop "a more scientifically literate society" (Engineering Council, 2017).

Dancing to a different tune: transferability of disciplinary perspectives

Recognising the numerous and increasingly complex intersections between music and engineering, notably in areas such as acoustics, psychoacoustics, music technology and sound recording, these subjects have, nevertheless, been brought together in this chapter in part because of their notional differences and perceived distance in terms of wider educational approaches and 'disciplinary cultures' (Becher, 2006). Neatly delineated in most industrialised education systems, science and the arts are commonly distinguished as different domains of creativity and most certainly different areas of educational activity. From a socio-constructivist and sociocultural perspective (Krauss, 2012), tribes and territories are clearly evident. Kaufman's 'Domains of Creativity Scale' (K-DOCS), for example, delineating "Everyday, Scholarly, Performance, Science, and the Arts" (McKay Et. al, 2017), universities themselves often locate disciplines in separate spaces and embody very different epistemological beliefs and behaviours (Kember Et. al, 2014).

Considering the focus on creativity and innovation in STEM education in this book however, this chapter is born from a fascination with subject identity in higher education and a perhaps whimsical interest in exploring difference and the boundaries between disciplines a potentially rich basis for the development of new pedagogical ideas. Rather than investigate the wide range of innovations evident in STEM education in the context of creativity, including problem/research-based, active and online learning, the purpose of this chapter is to contextualise and describe a series of approaches to the development of creativity in engineering disciplines through a music education perspective. Considering the potential for insight through exploration of contrasts and variations in disciplinary practice and perspectives, and developed under the precept that difference is valuable, meaningful and interesting in and of itself, as well as emblematic of creativity, the aim is to focus on uncommon ground as the basis for the design of new pedagogical ideas.

Music has also been selected in this analysis in part because of the evidence suggesting transferable educational benefits (Jones, 2018). From Rhode Island School of Design's 'STEM to STEAM' initiative, advocating for the value of an arts perspective in a focus on 'Science, Technology, Engineering and Maths', a range of positive educational impacts are associated with musical activity. From 'spatiotemporal reasoning skills' (Črnčec Et. al, 2006), increases in intelligence and memory (Sala & Gobet, 2017; Chamberlain Et. al. 2014), and benefits for "motor, language, social, cognitive, and academic abilities" (Dumont Et. al. 2017), the potential for the positive impact of arts-based activity on cognition, meta-cognition and communication (Biasutti, 2017) are widely documented. However, recognising that these debates are contestable and generally focused on early-years education rather than university study, the intention here in not so much to evaluate the potential benefits for 'adding' musical experience to undergraduate engineering curriculum, rather to use a deep enculturation within musicianship and music education as a basis for informing a fresh perspective of engineering as a subject discipline. Nevertheless, creativity being so closely associated with imagination, and imagination being the "cognitive basis of musical activity" (Hargreaves, 2012), there is at least a rationale for this approach. As outlined in Figure 1 below, as well as developing many general graduate attributes, music is also associated with number of more specific transferable skill-sets related to the 'expressionist, scientific rationalist, and reconstructivist' approach of art education (Hickman, 2010).

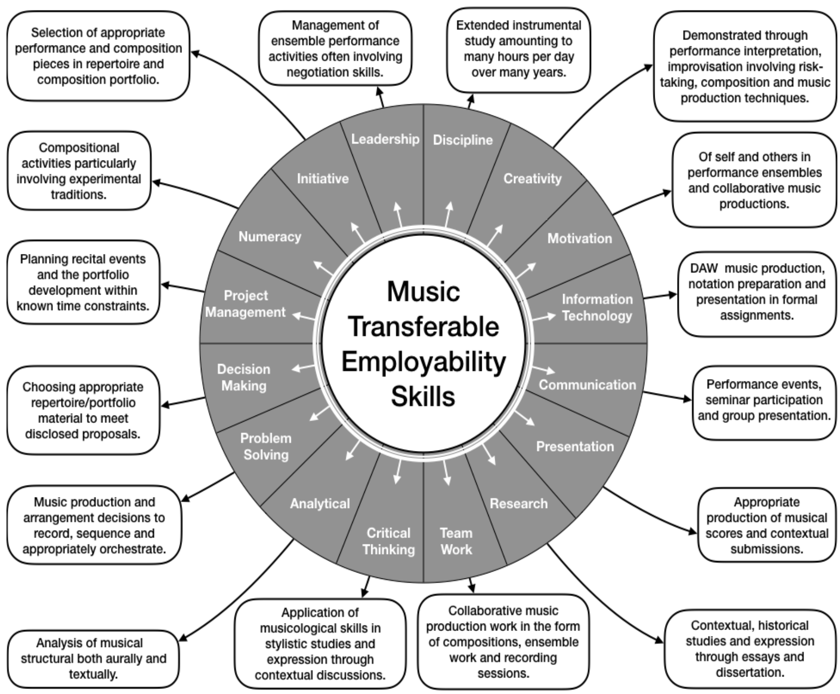

Figure 1: Considering transferable employability skills of musicians

It is important to note of course that in corollary, an engineering perspective of musical education may well of course be equally valuable, and to acknowledge that disciplinary grounding is an evident factor in potential bias in this analysis. We acknowledge that “A creative product in different domains is measured against the norms of that domain, with its own rules, approaches and conceptions of creativity” (Read & Petocz, 2004) but nevertheless embrace that reality. We argue that interdisciplinary perspectives provide an opportunity to enrich debates about, and approaches to, the development of creative university graduates in ways relevant to all disciplines, whether born of bias or ignorance. Difference is always difference, and difference is always new.

Equally, it is also important to note that no authority over ‘creativity’ is assumed in disciplinary terms in this analysis. Whilst there may be greater openness to creativity in terms of central disciplinary discourse in music, we note established models of creative engineering including the TRIZ method (Busov Et. al. 1999) described as “the most comprehensive systematic innovation and creativity methodology available to mankind” (Mann, 2000) and acknowledge the parity of significance between the greatest musical and engineering achievements. Nevertheless, accepting the arguments that the future needs of society would benefit from more creative graduates (quantitatively and qualitatively), and noting the emergence of the concept of 'T-Shaped' graduates with increased boundary crossing competencies, this chapter considers how interdisciplinarity and interdisciplinary perspectives might support the development of new pedagogical ideas capable both of increasing the engagement with engineering study as well as the creativity of engineering graduates.

Reflecting wider issues of borders, territory and hybridity (Newman in Wastl-Walter, ed. 2011), the boundaries between disciplines in higher education may be becoming more contestable and porous, in part in response to changes in industry, but disconnections still remain deeply entrenched in disciplinary identity in educational systems. A consequence of increasing complexity and interconnection, whilst disciplines have always evolved and changed, there is an increasing sense of fluidity in both the structure and application of knowledge often not reflected in the structures of university departments, research activities, and courses of study. Whilst there is increasing opportunity for students to study combined subjects in UK higher education (Carr Et. al. 2014), by far the largest proportion of undergraduate students remain engaged with 'specialist' degree subjects and academic staff aligned with a defined disciplinary area of expertise. Engineering departments remain predominantly separated from corresponding Arts departments.

First exploring the paradox of discipline, considering both the limiting factors related to disciplinary isolation and the value of clear structures for the development of creativity, the study then moves to consider the relationships between music and engineering disciplines' perspectives of creativity and related pedagogical cultures and practices. Focusing in particular on areas of divergence and difference, the chapter concludes with a series of proposals and pedagogical models for adaptation of approaches to engineering education with particular emphasis on the design of undergraduate engineering.

The curious paradox is that when I accept myself as I am, I can change."
Carol Rogers.

The paradox of discipline

Creativity and the constriction of discipline: an inflexible innovation engine

There is more than one paradox at the heart of the academic disciplines in higher education with respect to innovation. Whilst widely advocated and supported, innovation nevertheless remains incremental in practice. Disciplinary structures, whilst flexible and increasingly porous, are nevertheless robust, and the comparability of educational approaches in the modern era to those of centuries ago are frequently opened for criticism. For example, in the context of wider debates in the UK higher education sector about ‘teaching intensity’ as a proxy measure of teaching quality, whilst the University of Northampton have openly moved away from traditional lectures towards more active-learning pedagogies (JISC, 2018), traditional teaching methods predominate, and there is a prevailing sense that education can achieve different outcomes using broadly the same methodology. There remain widespread assumptions “underlying common metaphors for learning” including time and place, product delivery (information processing and transmission models), and systems and process (steps, levels and mechanisms plus regulation and control) (Wilson, 1996).

Creativity has never more evident in the thinking of academic departments but remains arguably more focused on student outcomes than approaches to learning and teaching. Universities continue to drive the research highlighting the increasing pace of industrial change and related uncertainty about the knowledge and skills necessary to thrive, whilst conserving and maintaining practices in learning and teaching as mere colourful echoes of previous eras. Students continue to sit in lecture halls listening and taking notes and learning evaluated through a variety of proxy measures often directly modelled on forms of activity familiar to university study for nearly a millennium. Because they, seemingly, ‘work’.

As with any social construct established in some cases over millennia, the concept of a ‘subject’ in terms of educational study is in most cases firmly established in industrialised educational systems, as is the pedagogic practice related to those subjects; a ‘maths lesson’ is what a maths lesson is; you learn music by ‘doing this’; this subject is more practical; that subject is more theoretical, etc. Whilst there are of course variations in practice, the presence of notional differences in educational practice between disciplines remains a consistent feature of global education systems. Disciplines change and adapt over time in an ‘open’ mode, but are simultaneously ‘closed’, definable by surface features and boundaries, the practices and perspectives within often isolated in pedagogic terms.

At worst, boundaries to innovation in universities can be profound:

> “the absence of a collegial culture of pedagogical supervision that allows the development and the assessment of practices; the scarcity of institutional structures that support and encourage innovation and professional development; maintenance of the separation between research and teaching, and the devaluation of teaching in academic careers” (Stano, & Vieira, 2014).

Related to disciplinary innovation, barriers to innovation in higher education generally fall into the following perspective category areas:

1. The curriculum is full

Considering curricula, given the etymological origins in Latin, ‘a running, course, career’, there is nevertheless a tendency to conflate ‘curriculum’ with ‘syllabus’ and to focus more on content than process. Having highlighted the evident and exponential increase in the complexity and sophistication of subject content associated with engineering disciplines, it is perhaps understandable that any subject struggling to accommodate new content into a framework reluctant to jettison old content, would feel constrained. Equally, evident in most experiences of course development and approval in universities, there is often an element of contention in determining the relative significance or emphasis to be given to particular areas of established engineering subjects. The suggestion that novel or unfamiliar activities or subject content should be given space is clearly a difficult argument.

Identifying the prevalence of 'inbreeding' and 'academic silos' within disciplines, Cohen and Lloyd (2014) highlight the potential for such structures of accountability and consequent survival risk to influence protective behaviours and to drive the development of more rigid boundaries, creating tensions between notions of specialism and generalism, the potential for "myopic views of complex phenomena" (Ibid: 196) through 'discipline-specific' approaches to pedagogical research, and questions about the relationship between discipline-specific knowledge or 'DPK' and 'general pedagogical knowledge' or 'GPK' (Berthiaume in Fry Et. al. 2009: 215).

Highlighting 'syntactic, semantic, and pragmatic' boundaries between disciplines, Carlile (2004) highlights the "negative consequences of the path-dependent nature of knowledge" as a consequence of isolation. Carr (Et. al, 2014), citing Segal (2009), acknowledges that "those who do not leave their home disciplines are not ostriches" (p. 6), but identifies the continued tendency towards the 'ivory tower' and "academic endeavour sequestered away from the distractions and irrelevancies of the wider world" (p. 5).

The evolution of academic subject disciplines in education systems represents a fascinating history. From Plato's olive grove to the relative simplicity of Medieval universities including the University of Paris in the thirteenth century, incorporating Theology, Medicine, Canon Law and Arts, the relatively short list of subjects associated with the liberal arts gave way through the secularisation of higher education to a proliferation and separation of disciplinary areas to add languages, sociology, sciences, and psychology, whilst the rapid expansion of higher education in the twentieth century coincided with a further diversification of subject disciplines particularly in the social sciences. Nearly a thousand years of higher education within the European tradition is marked by an almost consistent increase in specialism, delineation and differentiation, and away from generalism. In UK higher education in 2018, subjects are codified in a variety of different ways but are categorized by the Higher Education Statistics Agency (HESA) according to nineteen broad subject areas in the JACS 3.0 subject codes, and, for undergraduate subjects, are now described by sixty-two Subject Benchmark Statements as part of the UK Quality Code (QAA).

Cohen and Lloyd (2014) highlight the evolutionary aspects of disciplinary development including, for example, a focus on discipline 'speciation', such as with agriculture, developing into agronomy, animal sciences and food science; heterosis and hybridisation, such as with the emergence of fields such as educational psychology, and; extinction, such as with the decline of secretarial studies with the emergence of computing and IT disciplines. Recognising the relative modernity of established disciplines as a product of both business and accounting structures both in institutional terms and in terms of research, citing work by Biglan (1973) in classifying disciplines according to pure vs applied disciplines, life vs non-life context, and hard vs soft disciplines, they place Natural Sciences, Arts & Humanities, Applied Science, and Social and Creative Professions at the extreme quadrants of a basic disciplinary framework, differentiating between the disciplines based broadly on three key areas: Focus of investigation, research methodology, and their epistemologies.

Ultimately, complex structures have developed that both support and constrain educational disciplines. Constricts of accountability in UK higher education (Fry Et. al (2009) including the Research Excellence Framework (REF), Teaching Excellence Framework (TEF), Destination of Leavers from Higher education (DLHE), graduate destinations and 'Longitudinal Educational Outcomes' (LEO), plus professional body accreditation processes and requirements, overlap with historical assumptions and epistemologies to constrain movement and change.

External to disciplines and related to many of the same factors driving the maintenance of disciplinary structures, are consequent notions that some subjects matter more than others for the development of individuals and the wider social good, arts subjects often being amongst the first to face cuts in educational funding, and maths the last. These priorities may shift over time and by context, but most educational systems place greater importance on literacy ('Language') and numeracy ('Mathematics') than spatial ('Dance', 'Sport'), aural ('Music'), or visual ('Art') domains. Indeed, the active holding back of arts education in many educational policies, despite the concurrent focus on developing creativity, has been recognised as anomalous (Livingston, 2010).

Whilst great emphasis has been placed on the value of innovation in learning and teaching for many years, so has the process of disciplinary refinement and the settlement of heritage. The very notion of discipline implies boundary and threshold. Indeed, related to the engineering skills-crisis highlighted in the introduction to this chapter, one challenge identified in developing engagement with higher level study of engineering is the "arts versus science divide" prevalent in many educational systems (Royal Academy of Engineering, 2016). Indeed, as observed by House Et. al. (2017) in discussing the frequent segregation of design and analysis, "engineering design studios are intended to combat students' tendency to dismiss or subordinate the skills, methods, and bodies of knowledge outside of their own major discipline or specialty."

2. It's a waste of time (innovation fatigue/cynicism)

It is also the case that there can be suspicion and active resistance to innovation in pedagogic practice. 'Innovation fatigue' can set in in educational environments with highly dynamic approaches to 'initiatives' and suitable stretch in terms of time and energy. Most experienced academics will recall systems, processes, platforms, and educational ideas that have come and gone, of innovations that failed or did not bare the promised fruit. The consequence of this can sometimes be an informed scepticism at best, but often active resistance, given the evident reality of innovation for innovation's sake.

3. It's working already (fear of 'rocking the boat')

Furthermore, given the increasing significance associated with 'student satisfaction' as a proxy measure for determining the quality of teaching in higher education institutions, notably in the UK's 'Teaching Excellence Framework' (TEF), there is the potential for a 'tyranny of success' mentality and for engineering degree programmes that are successful, perhaps quite reasonably so, to entrench approaches and subject content. Universities want to have the best department doing what competitors are doing, not be a leader in a field of one. Equally, even in cases where actions are taken to improve student success or learning experience, there is a widespread tendency in higher education towards modelling of practice change on patterns of success elsewhere in mitigation of risk, rather than rewards being perceived in terms of innovation and distinction.

4. Innovation is too risky (failure too costly)

In addition to the 'tyranny of success' is the perception of risk. Many universities actively use student feedback for annual performance appraisal and promotion purposes and higher education systems such as that of the UK incorporate significant emphasis on 'student satisfaction' in related league table calculations. Consequently, beyond seeking to avoid 'rocking the boat', innovation in the fullest sense, that is to say approaches or activities without precedent or substantial evidence of efficacy, may routinely be judged unfavourably in terms of risk (Hill, 2011).

5. Market regulation is too constrictive (scope for change is limited)

Change is also limited by the increasing marketisation of higher education. Notable in UK higher education is at least the institutional perception of the impact of Competition and Markets Authority (CMA) regulatory requirements. With students increasingly treated as customers of universities with consequent consumer rights protection, from the point of accepting a place on a university course, the institution is obliged to make that 'product' available for the necessary duration and is inhibited from undertaking substantive changes to either structure or content without at least the informed consent from all students.

6. There isn't time (capacity for change is scarce)

Finally, and perhaps most significantly, there is the wider issue of time. With more than one third of academics reporting workloads exceeding fifty hours a week and already contributing to stress and wellbeing problems (Kinman & Wray, 2013), the capacity to overcome and even to consider working through the preceding challenges is further compromised.

In addition to the many general factors than inhibit creativity (Lennox Et. al, 2016) there are also a range of factors determining approaches to university study and maintaining conception of subject discipline that both constrain and support, separate and secure, and an intersection of points 1-6 above evident in most higher education environments. It is ironic that marketisation of higher education in the UK in particular has coincided with, and even been driven by, the same focus on creativity and innovation. Just when risk-taking and diversity in higher education and disciplinary approaches are perhaps most required, systems are implemented to let "failing universities go to the wall" (UK Universities Minister, Jo Johnson, in Espinoza, 2015). Flexibility and change have never been more required or been riskier.

Considering Figure 2 below, reflecting wider observations of a drift away from play and creativity through levels of education towards more theoretical approaches (Zbainos & Anastasopoulou, 2012), the issue of domain complexity and educational systems and context reflect the key factors inhibiting innovation or capacity for creativity. In one respect, initial play and experimentation through childhood development gives way to standardised educational structures and increasing complexity of subject knowledge and application. The intersection with wider organisational structures in higher education in combination with this complexity and educational heritage further compound the capacity for innovation in practice and increase potential for standardisation of approaches.

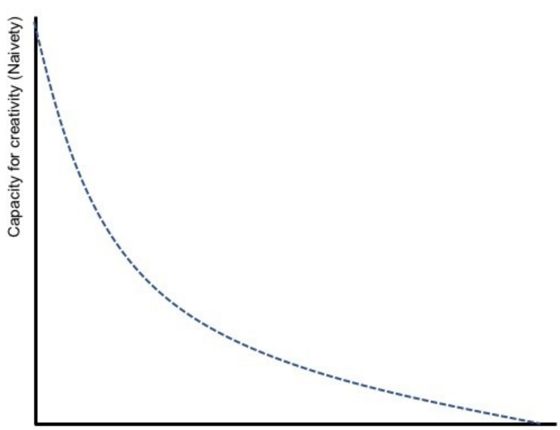

Figure 2: Considering creativity and domain complexity

Creativity and the liberation of discipline

Considering the challenges and constraints, one may wonder how any creativity manages to survive. The reality is, of course, that the same systems and structures provide the essential context for creativity to be possible at all. With respect to the relationship between creativity and discipline, of course all creative endeavour requires a context for recognition and a framework for innovation to occur. Boundaries are an inherent requirement of creativity, and indeed often represent a catalyst *for* creativity. After all, how can novelty be identified except against a clearly defined and widely acknowledged baseline?

As observed by Rowlands (2011), "creativity cannot be seen purely in terms of novel ideas [...] it is intrinsically bound with the teaching of the academic disciplines", and that "creativity involves both thinking within the constraints of the discipline and challenging those constraints". As highlighted by Sternberg (2006: 89), "One cannot move beyond where a field is if one does not know where it is" or demonstrate escapology without the straightjacket. Whilst Sternberg also highlights in the very same point that experts can make "more and deeper use of the existing structure and hence have to reformulate their thinking more than novices do when there is a deep-structural change in the rules of the game", the deficit of naivety also constituting greater flexibility and unencumberance, research over the decades has moved away from domain general perspectives of creativity as something approximating intelligence, towards a greater consensus towards domain specificity, especially utilising Consensual Assessment Techniques (CAT) (Amabile, 1983).

Highlighting the central importance of motivation in non-domain specific attributes of creativity, Kaufman & Baer (2005) also identify the evidence of divergent thinking ability not being transferable, there being "big differences in what one needs to know, and what one needs to know how to do, in order to be creative when undertaking different tasks" in a given domain (Ibid: 326). Further highlighting the development of micro-domains and high levels of specialism developing along a line inversely related to flexibility or transferability, there are also "differences between domains in the kinds of cognitive processes, specific content knowledge, personality traits, or ways of working that lead to creative performance" (p. 313).

Noting a shared recognition of creativity of being present in all university disciplines and as being simply a "departure from tradition", Marquis & Vajoczki (2012: 7) note an interesting consistency in focusing on novelty or originality over utility (Ibid: 11) and of creativity being a personal characteristic shaped by context (Ibid: 6). There being a clear distinction between disciplinary creativity and 'general' creativity (Charyton & Merill, 2013), whilst conceptions of discipline and reality of disciplinary study may limit scope for innovation, hence the focus on paradox in the title of this section, these constraints represent an essential condition for creativity to emerge.

Recognising an inherent ‘tensegrity’ in academia, a sense of the sustainability and cohesion of systems being bound up with many of the same pressures, given the underlying focus on creativity in this text in particular, and the theoretical and practical intersectionality of creativity and wellbeing (Hughes & Wilson, 2017), the potential to enrich lives and to create meaning are perhaps the two most compelling rationales for promoting the value of a musical perspective. The purpose of this text, whilst focused on illustrating the benefits in general of interdisciplinary perspectives, is also to develop and present adaptable and applicable models capable not only of overcoming the challenges to innovation in education outlined earlier in this text, but also potentially as solutions for them. After all, music creates space and personalised opportunities for safety.

"Music is an art that touches the depth of human existence; an art of sounds that crosses all borders."
Daniel Barenboim.

The dynamic borders of disciplines: Interdisciplinary perspectives of Engineering and Music

Carr Et. al. (2014) identifies ‘interdisciplinarity’ to refer to a range of specific practices in educational contexts:

- Multi-disciplinary: sharing learning, teaching or assessment activities between disciplines;
- Cross-disciplinary: exploring different disciplinary perspectives;
- Trans-disciplinary: blurring the boundaries between disciplinary approaches;
- Collaborative mode: combined approaches but within disciplines;
- Integrated mode: combined approach but working across disciplines;
- Intra-disciplinary: collaboration within a discipline.

Consequently, the focus on this analysis tends towards cross-disciplinary and trans-disciplinary.

It is tempting to consider disciplinary boundaries as analogous to geographical and geopolitical borders, reflecting tension and fortification. Whilst Barry Et. al (2008), for example, highlight the “agonism and antagonism that often characterize relations between disciplinary and interdisciplinary research”, they also identify such contexts as developing distinctive approaches to innovation. Dillon (2008) presents a compelling case for the “creative and integrative” value of ‘cross-disciplinary’ work whilst Walker & Nocorine (2007) highlight specifically the value of communities of practice, networked expertise and the potential for “boundary-crossing competence” through more ‘horizontal’ rather than ‘vertical’ educational systems, reflecting the focus on ‘T-shaped’ professionals for the future, incorporating boundary crossing expertise (T-Academy, 2018). As stated by David Norman

(Wastl-Walter, 2011), there has been a "Renaissance in the study of borders" and an extension beyond cartographic and geographical perspectives towards the broader significance of intersectionality and contestable spaces, leading to an evident increase in the bibliographic interchange and flow of ideas (Lindholm-Romantschuk, 1998).

Exploring the management of knowledge across boundaries, Carlile (2004) describes three progressively complex thresholds--syntactic, semantic, and pragmatic, and highlights processes of 'transfer, translation, and transformation'. Reflecting the value of 'analogical distance' and 'within- and between-domain(s)' for creative problem solving (Christensen & Schunn, 2007), also significant is the potential for a novice perspective to bring less 'schema-driven' analogising (Ball, Et. al).

Whilst there may be evidence of students of arts disciplines scoring higher for openness and self-assessed creativity (Kaufman Et. al 2013) we also note the metacognitive complexity of creativity and that self-perceptions do not necessarily reflect reality (Pretz Et. al 2014). Highlighting the 'American Idol Effect' (Kaufman Et. al. 2010), naivety in a given domain can too frequently coincide with flawed creative judgement. Equally, some evidence indicates the potential for creative metacognition (CMC) to reveal closer correlations between self-perception and expert judgement (Kaufman Et. al, 2016).

Reflecting conceptions of various conceptual continua, E.g. from scientific rationalism to artistic romanticism, theoretical to applied, 'hard' vs 'soft', in the character of disciplines, Figure 3 below is an attempt to encapsulate key potential disciplinary differences between engineering and music.

Engineering	**Music**
Precision	Expression
Structure	Form
Mechanism	Ensemble
Interface	Experience
Externality	Internalisation
Principles	Frameworks
Fixed	Fluid
Field	Style
Recognition	Celebration
Tradition	Heritage

Figure 3: Contestable conceptual differences between engineering and music.

From a sociocultural perspective, music and engineering occupy very different spaces. Taking the Subject Benchmark Statements for undergraduate Music and Engineering study within the UK higher education context (QAA) for example, some parallels and differences are apparent with respect to the treatment and perspective of creativity. Both identify creativity as a graduate trait, in Engineering generally in conjunction with innovation in being able to manage change and develop "ethically sound sustainable solutions" (QAA, 2016b: 2.3 & 4.3), and in Music in more nuanced terms including explicit reference to creativity and 'critical thinking' through engagement with music in "sophisticated ways" (QAA, 2016a: 2.8), and in terms of attributes including skills of "reflection, discipline, entrepreneurship, communication and teamwork, allied with cultural, historical, sociological, aesthetic and theoretical understanding" (Ibid: 3.1).

Greater variation is evident with respect to other areas of creative focus. Engineers are distinguished from scientists precisely because of the ability "to conceive, make and actually bring to fruition something which has never existed before" (QAA, 2016b: 2.3). A fundamental characteristic of engineering graduates, a "creative way of approaching all engineering challenges" is highlighted as a "way of thinking" present in "all engineering disciplines" (Ibid: 3.1). Music incorporates more references to creative activity overall, including, notably, "contextual understanding of how their creative musical practice links to those of others in different contexts", in terms of personal skills in "maintaining confidence in one's own creative work", and includes an explicit list of six key 'Creative skills' relevant to music graduates:

I. Conception: the ability to conceive musical ideas and to manipulate them in an inventive and individual way.
II. Elaboration: the ability to develop materials into well-formed and coherent musical structures.
III. Adaptation: the ability to work idiomatically with a variety of musical styles, materials (instruments, voices), and media (film, electronic and electro-acoustic resources) and to manipulate them as desired.
IV. Presentation: the ability to use a range of techniques to enable effective communication of musical intentions clearly to others (performers, audiences).
V. Collaboration: the ability to work with co-creators, including those from different artistic disciplines.
VI. Preservation: the ability to document creative practice, with consideration for issues of both dissemination and impact. (QAA, 2016a)

The extent to which the Subject Benchmark Statements define curriculum is limited but is arguably more explicit in Music. Engineering identifies a reliance on "three core elements" (2.3), namely "scientific principles, mathematics, and realisation". More explicit and granular, perhaps reflecting a notionally greater diversity of discipline, Music acknowledges that any reference to content must "of necessity be indicative rather than prescriptive" (2.3) but highlights a considerable breadth of content across twenty-four sub-categories including acoustics, ethnomusicology, technology, psychology and performance.

Clearly both Engineering and Music reflect parallel ambitions to develop creativity as a graduate attribute and a shared focus on ‘creative invention’, ‘conceptual synthesis’ and ‘structured imagination’ related to ‘creative cognition’ (Finke Et. al. 1992; 1999). Considering the differences between educational approaches to music and engineering, more conspicuous variations become apparent. Firstly, across all known cultures, musical experience is deeply ingrained with childhood development and learning. Furthermore, whilst there is increasing evidence of home tutoring across a range of educational subjects, the social practice of formal engagement with instrumental lessons in music is far more widespread than any equivalent engineering tuition. Requiring often ten years of development and supplementary tuition to achieve the standards required by many leading conservatoires of music, epitomising Malcolm Gladwell’s albeit contentious ‘10,000 hours’ rule, there is a disconnection between higher level instrumental expertise supported by many supplementary examination structures and standards frameworks. Whilst acknowledging the tendency towards greater emphasis within formal school curricula towards science and technology, in general extra-curricular contexts, acknowledging the existence of ‘engineering clubs’ and ‘science shows’ particularly in the US school system, musical activity retains more deeply established institutions, standards frameworks and opportunities for engagement.

Ultimately, whilst engineering builds the most impressive physical structures, music has developed the more intricate structures of social awareness and cultural engagement. Whilst numerous forms of reward and recognition exist for engineering excellence, with figures such as Isambard Kingdom Brunel for example achieving huge fame and historical significance, greater prominence is evident with respect to musicians and greater economic rewards available for related personal success more generally. Whilst engineering is celebrated and preserved for public attention, musical engagement is unavoidable in most public or private spaces and musical activity routinely involves crowds of thousands. Whilst individual engineering exceptionalism and genius is celebrated, musical expertise is explicit in a focus on personal creativity and expression. Engineering is collective and pragmatic, music is personal and romantic.

Acknowledging the distinctiveness of disciplinary context in terms of differentiation in expertise and application, potentially as significant as practice in developing different perspectives of disciplinary creativity is that of the discourse surrounding or framing it. One interpretation of the semantic differences between art and science may simply be that arts disciplines tend towards a more nuanced and granular view of creativity aligned with Kaufman and Beghetto’s (2009) ‘4C’ model reflecting a spectrum from everyday and personal creativity, to creative genius, whilst scientific disciplines tend towards the reification of disciplinary creativity more narrowly banded towards the genius. Whilst it may be the case that music is simply less discriminating as a discipline and too willing to begin interpretation in creative terms, labelling basic competences as creative without necessary justification and too focused on "trivial rather than important creative accomplishments" (Sternberg & Lubart, 2002), it may equally be true that engineering is correspondingly ungenerous with the recognition of creativity.

Embracing difference on common ground: If engineering was a musical instrument

Recognising the obstacles and barriers to creativity and innovation in higher education, and the paradox of these obstacles forming part of the very structures necessary for creativity as outlined previously in this chapter, it is nevertheless acknowledged that influencing change to pedagogic practice or perspective is challenging. However, highlighting the potential for constructive alignment (Biggs, 1999) to provide a framework capable of accommodating different disciplinary perspectives, Marquis & Vajoczki (2012) also note that:

> *"provided that instructors in any discipline (a) name the development of creativity as an intended learning outcome for their students (as a number of respondents across Faculties did in this study), (b) develop learning activities designed to help students meet those outcomes, and (c) construct assessments that encourage creativity and measure its relative achievement, student learning of creativity should be enhanced."* (Ibid: 12).

The starting point is therefore more straightforward. Given that the potential for engineering student creativity to be enhanced through active teaching of creativity (Cropley & Cropley, 2010), if engineering was more musical, it could simply be more explicit and more structured in the recognition of, and focus on, creativity itself.

Considering approaches to 'musical' models for engineering education more broadly, it is tempting simply to suggest that engineering would benefit from developing parallel structures to mimic those of music. For example, whilst the Royal Academy of Engineering in the UK support an extensive programme of educational activities and outreach services, the Associated Board of the Royal of the Royal Schools of Music (ABRSM) support a globally recognised instrumental standards framework and examination scheme designed to engage very young learners. Recognising the distinctiveness of instrumental study in music there are, nevertheless, parallels evident with engineering. Given that most engineers recall early fascination with making and building, or exploration of theoretical concepts and ideas, the potential to develop supplementary standards frameworks as opportunities to structure engagement with engineering at earlier ages has clear possibilities. Whilst there are numerous opportunities for the development of supplementary credentials and qualifications in engineering subjects and related technical expertise, a more explicit context for the recognition and celebration of engineering skills would provide perhaps one way of addressing the skills shortages identified in the introduction of this text.

Furthermore, recognising the existence of defined 'music theory' qualifications aligned with related instrumental practice in music, perhaps the common feature with engineering is that of a practical emphasis on making and building. Consequently, in order to become more 'musical', there is scope to consider the extent to which engineering mastery might stem from personal mastery and more focused expertise (rather than the other way around). It being notable that 'general' musical expertise tends to develop from 'specific' musical expertise in the context of instrumental study in music in contrast to most engineering disciplines, there is value in considering how this might be realised more actively in engineering study. For example, given the wider transferable skills development opportunities presented both by inaugurating and managing regimes of practice and through self-regulation and reflection in preparation for examination or performance, opportunities for the development of mastery in engineering to be structured, recognised and rewarded, could further develop opportunities for engagement.

With respect to specific aspects of musical practice capable of transference into an engineering disciplinary context, musical study tends to incorporate a combination of the following activities:

1. Individual mastery

With respect to individual practice and self-directed study, instrumental exams incorporate requirements for competence in an increasingly complex series of rudimentary techniques and musical knowledge. Scales, modes and arpeggios, as well as aural skills in being to recognise key musical features and interact with unfamiliar musical contexts in confident and meaningful ways, develop overall structures for knowledge and technique. From an engineering perspective and related to the previous point about individual skills, notable here is the focus on framework competency. Whilst of course engineering has underlying technical competencies, the potential for these to be structured into 'drill exercises', synonymous with the slow and attentive approach to the development of skills in playing a G Minor scale properly on a violin, is intriguing. Notable in the case of musical training, structured practice is about focusing on areas of weakness and uncertainty in structured ways. Whilst rote learning of times-tables in early years school education reflects similar patterns, the combination with self-directed study reflects a key difference. Given the significant breadth of fine motor skills and technical abilities relevant to engineering disciplines, there is clear scope to consider how appropriate frameworks, reward and recognition structures might encourage such learning behaviours.

2. Ensemble and collaboration

As well as opportunities for considering individualised learning experience through music, collaborative activities are as significant. It is not difficult to consider activities in engineering analogous to ensemble music making. With clear evidence of the value of collaborative and cooperative learning, at least in terms of student engagement (Ahn & Nelson, 2018), and in the related value of improvisational approaches, creative collaboration and learning through error (Gerber, 2007), the formal 'playfulness' and the ephemeral nature of performed musical creativity, perhaps less inhibited by the more temporal and tangible constricts of an aimed-for 'successful product' in engineering, provides a safe space for experimentation. Musical error in ensemble is the basis for growth and is quickly superseded and moved beyond. Whilst error in collaborative engineering contexts can often provide the basis for innovation, it is more routinely problematic and in educational contexts, associated with failure than innovation. Recognising improvisation as active 'experimentation' (Wohlin Et al. 2012) and as a potential 'engine' of resilience (Grøtan, Et. al, 2008), improvisation and extemporisation have important status in the education of music and represent a space through which individual creativity is developed through collaborative creativity (Wilson & Brown, 2014).

Recognising established research in the area of improvisation and engineering, Ludovice Et. al (2010) conclude the need for "more comprehensive refinement of idea space" for technical improvisation. Whilst stylistic and instrumental constraints may reflect refined 'idea spaces', improvisation in music also tends to embrace fuzzier boundaries as the basis for experimentation rather than an inhibitor of it.

3. *Repertoire*

A further point of note is the relationship between musical practice and repertoire. Not seeking to argue the potential for engineering 'repertoire' to achieve the same level of cultural significance as that of music, there is, nevertheless, opportunity for considering how the heritage of engineering might be considered more 'repertoire-like'. Significant emphasis is placed on music listening and the development of knowledge and understanding of the heritage of musical ideas. Developing a close relationship between technical mastery through practical engagement with musical repertoire, time is also devoted to musical listening and the processing of musical experience.

4. *Composition*

Closely related to ensemble music improvisation, composition in music has perhaps the most direct parallels with engineering in terms of the development of design and 'making'. Indeed, given the intersection between the disciplines in many areas of computer-music and in the technical complexity of modern live music performance and broadcast, many modern processes of musical composition are highly technical in themselves. Nevertheless, of significance in the context of this analysis is the domain-idiolect dynamic evident in the composition of music (Brown & Wilson, 2015). In the process of musical composition, and in frames of reference of reception and decoding, lie the twin interests in the development of stylistic competency and in personal expression and distinctiveness; the former without the latter providing for the bland and the generic. Essentially, music does not differ from engineering innovation in terms of the value placed on new and distinctive ideas, but music incorporates a more active focus on, and routine opportunities for, the development of distinctive forms of expression within the domain.

5. Direction

A distinctive aspect of musical education is the prevalence for opportunity to develop leadership skills and to engage in acts of direction. An inherent feature of the ensemble format, everyone follows key individuals and the overall group, and consequently, becomes part of a framework of leadership and followership. Acknowledging the frequent presence of a conductor or individual musical leader, musical ensembles nevertheless provide opportunities throughout all stages of musical development for the exercise of leadership, often, early in educational experience, in the active direction of others.

Considering the five broad areas of musical activity outlined above, in terms of specific developmental techniques related to music education, there are many established methods capable of informing approaches to engineering education. Some key examples include:

- The Dalcroze or Dalcroze Eurhythmics method advocating the learning of musical expression through movement;
- The Kodály method which uses child-development approaches and a range of teaching and learning techniques;
- The Suzuki method emphasising learning by ear, memorisation and through community;
- The Orff Schulwerk approach based in play.

Whilst all the methods listed above reflect features of good engineering education, particularly that of early-years education, an engineering approach to Dalcroze would certainly emphasise physical movement either through practical learning activity at scale or through further approaches to the rhythmic memorisation of information. The Kodály method might inform more codified structures of skills development and emphasis individual ability as the effective basis for developing further knowledge and skills, whilst insights from the Suzuki method highlight the potential value of greater emphasis on collective learning. Perhaps most enticing is the potential for the Orff Schulwerk approach to structure more playful approaches to the development of engineering skills and the most explicitly musical opportunity through deliberate incorporation and combination of drama, movement and speech into an active and playful learning setting.

From a higher education perspective, within the first week of study at most leading conservatoire of music, a typical instrumental student will have undertaken a solo lesson and been asked to perform examples from their current repertoire. Constituting a detailed diagnostic of individual technique and instrumental standards, all subsequent tuition would be based on developing the learner from 'where they are'. In addition, with the vast majority of instruments studied in the conservatoire sector aligned to at least one key ensemble, students will have undertaken their first collaborative music making often as the context through which new social connections are made. A considerable amount of time will have been invested in individual practice, both in general and in preparation for other performance activities, and the first masterclass undertaken. Often involving opportunity for direct comparison to contemporaries with the oversight of a tutor, competition and socialisation inaugurated in parallel.

Considering that most undergraduate engineering students would typically have a considerably different experience, perhaps the first key opportunity relates to the potential value of personalisation and a focus on individual expertise. Developing the notion of individual expertise developed previously in this text, the potential value and benefits of developing the focus on individual strengths and personal development needs is perhaps evident for all higher education subjects. With respect to masterclass and ensemble activity, engagement by undergraduate engineers with practical project-based activity through refined structures of competition and stretch, and mutual support and guidance, already lead to significant positive impact in many engineering courses but could be more widely utilised.

"In counterinsurgency operations, the human terrain is the decisive terrain."
David Petraeus

Summary and conclusions

The simple premise for this chapter was that the rich pedagogic heritage and agency of music education might inform fresh thinking in the approach to engineering education. Albeit an initially whimsical idea, this was nevertheless also predicated on the serious notion that deliberate consideration of the differences between disciplines may constitute an engaging 'provocation' in a creative thinking sense. The intention has been to explore how musicianship might inform approaches to something akin to a consideration of 'engineeringship', or a different social conception of engineering as a discipline, with the aim being to develop some ideas about how musical approaches might be pedagogically adaptable in terms of the development of creativity.

As highlighted in this chapter and in previous publications (Lennox, Wilson & Brown, 2016; Brown & Wilson, 2016; Wilson & Brown, 2016), barriers to creativity and innovation range from the subtle to the profound in all human circumstances and distinctively so in universities. Outliers, exceptions, and the profoundly unfamiliar, can struggle to influence the majority or 'find their way in' in terms of influence or space for accommodation. That was in no way a surprise in the context of the development of this analysis. However, the strictures in a higher education setting are identified as paradoxical in this respect given that they are also precisely the conditions necessary for creativity to emerge. Boundaries are annoying, but matter.

Perhaps the key conclusion of this study is that there is evident value in considering interdisciplinary perspectives when developing and designing of learning and teaching activities and curricula. Simple focus on "what is the most different" can support constructive and critical discussion. There is clear potential for creative metacognition (CMC) in engineering to be positively informed by musical disciplinary perspectives. For example, given the focus in CMC on self-knowledge and contextual knowledge, "knowing one's own creative strengths and limitations, [...] (and) knowing when, where, how, and why to be creative" (Kaufman & Beghetto, 2013), music does reflect rich and intricate structures of relevant and related educational knowledge spanning millennia. Music also manages both to be rigorous, fun, and socially engaging (Jones, 2009) which might be a critical factor in addressing issues of educational engagement and participation.

A more musical approach to engineering might ultimately involve more scaffolded structures and opportunities for the development of individual mastery with various practical or theoretical aspects of the discipline. The development of such mastery could be more immediately recognised and celebrated more visibly, and personal expression could perform a more important function in conceptions of technical and intellectual development. The expression of new ideas and the celebration of related creative thinking could be a more active part of social discourse, and opportunities for the study of engineering diversified at all levels of education. Perhaps most importantly, a more nuanced and granular approach to the discourse of creativity in engineering could be developed, more fully reflecting the apparent social and industrial needs of the future.

Ultimately, creativity is fundamentally, and simply, a tendency towards 'buying low and selling high' with ideas (Sternberg, 2006) and a capacity to identify their growth potential. Everyone understands, can recognise, and associate creative value with musical experience. It is culturally encoded. If technical and engineering expertise really is going to matter as much as it is projected to, we may need to consider how to nudge social consciousness more actively in this direction. Music and the arts may well be the best model possible to work from in achieving this.

Postscript

Writing for Wonkhe, the 'home of higher education wonks', Professor of English Literature at the University of Oxford, Sally Shuttleworth (2018), recently published an editorial challenging the trend towards decreasing choice in UK higher education. Challenging the basis by which disciplinary areas are judged in terms of their respective value, and the inevitable consequence of increasing marketisation in the university sector towards mass delivery and the decline of marginal subjects, the subject of the article resonates directly with the ideas developed in discussion of the 'paradox of discipline' in this chapter. Starkly titled "Our disciplines are disappearing, and we need to act now", seemingly, and unwittingly, just when the greatest diversity of talent is required, systems are conspiring to limit choice and to focus resources into areas of potentially flawed perceptions of importance. Sad though it is to reflect, it may be fanciful to propose notions of the interplay of ideas between disparate disciplines in universities, if those corresponding disciplines are in danger of no longer existing.

Bibliography

Ahn, B. & Nelson, M. (2018). Assessment of the effects of using the cooperative learning pedagogy in a hybrid mechanics of materials course. *International Journal of Mechanical Engineering Education 0(0)*, pp. 1–17. Sage Journals. Available online: http://dx.doi.org/10.1177/0306419018759734

Amabile, T. M. (1983). *The social psychology of creativity*. New York, NY: Springer-Verlag.

Baer, J. (2010). Is creativity domain specific? in J.C. Kaufman & R.J. Sternberg (Eds), *The Cambridge handbook of creativity* (pp. 321-341). Cambridge, NY: Cambridge UP.

Badran, I. (2007). Enhancing creativity and innovation in engineering education. *European Journal of Engineering Education, Vol. 32,* Issue 5, pp. 573-585. Available online: https://doi.org/10.1080/03043790701433061

Ball, L., Ormerod, T. C. & Morley, N. J. (2004). Spontaneous analogising in engineering design: a comparative analysis of experts and novices. *Journal of Design Studies, Vol. 25*, Issue 5, pp. 495-508. Available online: https://doi.org/10.1016/j.destud.2004.05.004.

Barry, A., Born, G. & Weszkalnys, G. (2008). Logics of interdisciplinarity. *Journal of Economy and Society, Vol. 37*, Issue 1, pp. 20-49. Taylor & Francis. Available online: https://doi.org/10.1080/03085140701760841

Becher, T. (1994). The significance of disciplinary differences. *Studies in Higher Education, Society for Research Into Higher Education*, pp. 151-161. Available online: https://doi.org/10.1080/03075079412331382007
Biasutti, M. (2017). Teaching Improvisation through Processes: Applications in Music Education and Implications for General Education. *Frontiers in Psychology*. Available online: https://doi.org/10.3389/fpsyg.2017.00911

Brown, M., & Wilson, C (2016) A Cage for the Muse and the Limits of Invention, in *Creativity in Arts, Science and Technology,* KIE Conference Book Series, Ed. Prof. F. Reisman.

Brown, M., & Wilson, C. (2015) *Conformity, Reformity and Deformity: Considering the Domain-Idiolect Dynamic,* in Reisman, F. K. ed. KIE Handbook of Creativity, KIE Conference Book Series. Available online: http://kiecon.org/Creativity%20Book%202015.pdf

Busov, B., Mann, D.L., Jirman, P. *TRIZ and Invention Machine: Methods and Systems For Creative Engineering and Education in the 21st Century.* Paper presented at 1st International Conference on Advanced Engineering Design, Prague, May 1999.

Carlile, P. R. (2004). Transferring, Translating, and Transforming: An Integrative Framework for Managing Knowledge Across Boundaries. *Journal of Organisation Science, Vol. 15*, Issue 5, pp. 555 - 568. Available online: https://doi.org/10.1287/orsc.1040.0094

Carr, P., Dennis, R. & Hand, R. (2014). Dancing with interdisciplinarity: strategies and practices in higher education Dance, Drama and Music. *The*

Higher Education Academy. Available online: https://www.heacademy.ac.uk/system/files/resources/dancing_with_interdisciplinarity_v2.pdf

Chamberlain, R., McManus, C., Brunswick, B., Rankin, Q., Riley, h. & Kanaif, R. (2014). Drawing on the right side of the brain: A voxel-based morphometry analysis of observational drawing. *NeuroImage, Vol. 96*, Issue 1, pp. 167-173, Elsevier. Available online: https://doi.org/10.1016/j.neuroimage.2014.03.062

Charyton, C. & Merill, J. A. (2013). Assessing General Creativity and Creative Engineering Design in First Year Engineering Students. *Research Journal for Engineering Education, Vol 98*, Issue 2, April 2009, pp. 145-156. Available online: https://doi.org/10.1002/j.2168-9830.2009.tb01013.x

Charyton, C. & Snelbecker, G. E. (2010). General, Artistic and Scientific Creativity Attributes of Engineering and Music Students, *Creativity Research Journal, Vol. 19*, 2007, Issue 2-3. Available online: https://doi.org/10.1080/10400410701397271

Christensen, B. T. & Schunn, C. D. (2007). The relationship of analogical distance to analogical function and preinventive structure: the case of engineering design. *Journal of Memory & Cognition, Vol. 35*, Issue 1, pp. 29-38. Available online: https://link.springer.com/article/10.3758/BF03195939

Chu, F., Kolodny, A., Maital, S. & Perlmutter, D. (2004). *The innovation paradox: reconciling creativity & discipline how winning organizations combine inspiration with perspiration.* Engineering Management Conference, 2004. Proceedings. 2004 IEEE International. Available online: https://doi.org/10.1109/IEMC.2004.1408831

Cohen, E., & Lloyd, S. (2014). Disciplinary evolution and the rise of the transdiscipline. *Informing Science: the International Journal of an Emerging Transdiscipline, 17*, pp. 189-215. Retrieved from http://www.inform.nu/Articles/Vol17/ISJv17p189-215Cohen0702.pdf

Črnčec, R., Wilson, S. J. & Prior, M. (2006). The Cognitive and Academic Benefits of Music to Children: Facts and fiction. J*ournal of Educational Psychology: An International Journal of Experimental Educational Psychology, Vol. 26*, Issue 4, pp. 579-594. Available online: https://doi.org/10.1080/01443410500342542

Cropley, D. H. & Cropley, A. J. (2010). Fostering Creativity in Engineering Undergraduates. *Journal of High Ability Studies, Vol. 11*, 2000, Issue 2, pp. 2017-219. Available online: https://doi.org/10.1080/13598130020001223

Cullen, J., Hadjivassiliou, K., Hamilton, E., Kelleher, J., Sommerlad, E. & Stern, E. (2002). *Review of Current Pedagogic Research and Practice in the Fields of Post-Compulsory Education and Lifelong Learning*. FINAL REPORT Submitted to the Economic and Social Research Council by The Tavistock Institute. Available online: http://www.leeds.ac.uk/educol/documents/00003147.htm

Dillon, P. (2008). A pedagogy of connection and boundary crossings: methodological and epistemological transactions in working across and between disciplines. *Innovations in Education and Teaching International Volume 45*, 2008 - Issue 3: CREATIVITY OR CONFORMITY IN HIGHER EDUCATION? pp. 255-262. Available online: https://doi.org/10.1080/14703290802176121

Dumont, E., Syurina, E. V., Feron, F. J. M., & Hooren, S-V. (2017). Music Interventions and Child Development: A Critical Review and Further Directions. *Frontiers in Psychology*. Available online: https://doi.org/10.3389/fpsyg.2017.01694

The Engineering Council (UK). (2017). *Engineering the Future: a vision for UK engineering*. Available online: https://www.engc.org.uk/engcdocuments/internet/Website/Engineering%20the%20future%20%E2%80%93%20a%20vision%20for%20UK%20engineering.pdf

The Engineer (2017) Available online: https://www.theengineer.co.uk/government-close-engineering-skills-gap/ (Accessed 5/5/18)

Espinoza, J. 2015. *'Let failing universities go to the wall,' says minister.* The Telegraph Online, 9th September 2015. Available online: https://www.telegraph.co.uk/education/universityeducation/11854659/Let-failing-universities-go-to-the-wall-says-minister.html

Finke, R. A., Ward, T. B., Smith, S. M. (1992). *Creative Cognition: Theory, Research, and Applications*. Bradford, The MIT Press.

Fry, H., Ketteridge, S. & Marshall, S. (2009). *A Handbook for Teaching and Learning in Higher Education: Enhancing Academic Practice* (Third Edition). New York: Routledge.

Gerber, E. (2007). *Improvisation principles and techniques for design*. CHI '07, Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, San Jose, California, USA — April 28 - May 03, 2007, pp. 1069-1072. Available online: https://doi.org/10.1145/1240624.1240786

Grøtan, T. O., Størseth, F., Rø, M. H. & Skjerve, A. B. (2008). *Resilience, Adaptation and Improvisation – increasing resilience by organising for successful improvisation.* Paper presented at the 3rd Symposium on Resilience Engineering Antibes, Juan-Les-Pins, France, October 28-30, 2008. Available online: https://pdfs.semanticscholar.org/cb59/39378d2970c758180d604ce1eb2bdb2c81ab.pdf

Hargreaves, D. J. (2012). Music imagination: Perception and production, beauty and creativity. *Psychology of Creativity, Vol. 40*, Issue 5, pp. 539-557, Sage. Available online: https://doi.org/10.1177/0305735612444893

HESA (2012). JACS 3.0 Principle Subject Codes: https://www.hesa.ac.uk/support/documentation/jacs/jacs3-principal
Hickman, R. (2010). *Why we make Art and Why It Is Taught*. Intellect Books. https://books.google.co.uk/books?id=pNrpMrzAm7wC&dq=scientific+rationalism+to+artistic+expressionism&source=gbs_navlinks_s

Hill, R. (2011). Risky Business. *Educational Developments Magazine, Issue 12.1,* pp. 1-3. Available online: https://www.seda.ac.uk/resources/files/publications_124_Educational%20Developments%2012.1.final.pdf

House, P., Brackin, P. & Watt, A. (2017). *Studio sessions: Engineering epistemology, design pedagogy, and rhetoric.* Professional Communication Conference (ProComm), 2017 IEEE International. DOI: 10.1109/IPCC.2017.8013948

Gareth, H. & Wilson, C. (2017). *From transcendence to general maintenance: Exploring the creativity and wellbeing dynamic in higher education*, in Reisman, F. Ed., *Creativity, Innovation and Wellbeing*. London: KIE Conference Publications. Available online at: https://derby.openrepository.com/derby/handle/10545/621907

JISC. (2018). *The large lecture (theatre) is dead…*Available online: https://www.jisc.ac.uk/news/the-large-lecture-theatre-is-dead-11-jan-2018

Johnson, M. & Hayes, M. J. (2015). A comparison of problem-based and didactic learning pedagogies on an electronics engineering course. *International Journal of Electrical Engineering Education, Sage Journals, Volume: 53,* Issue 1, pp. 3-22. Available online: https://doi.org/10.1177/0020720915592012

Jones, S. K. (2018). A comparative case study of non-music major participation in two contrasting collegiate choral ensembles. *Journal of Music Edu-*

cation Research, Vol. 20, Issue 2, pp. 252-264, Taylor & Francis. Available online: https://doi.org/10.1080/14613808.2016.1257594

Jones, B. D. (2009). Motivating Students to Engage in Learning: The MUSIC Model of Academic Motivation. *International Journal of Teaching and Learning in Higher Education, Vol. 21*, No. 2, pp. 272-285. Available online: https://files.eric.ed.gov/fulltext/EJ899315.pdf

Kaufman, J. C., Beghetto, R. A. & Watson, C. (2016). Creative metacognition and self-ratings of creative performance: A 4-C perspective. *Journal of Learning and Individual Differences, Vol. 51*, pp. 394-399. Available online: https://doi.org/10.1016/j.lindif.2015.05.004

Kaufman, J. C., Pumaccahua, T. T. & Holt, R. E. (2013). Personality and creativity in realistic, investigative, artistic, social, and enterprising college majors. J*ournal of Personality and Individual Differences, Vol. 54*, Issue 8, pp. 913-917. Available online: https://doi.org/10.1016/j.paid.2013.01.013

Kaufman, J. C. & Beghetto, R. A. (2013). In Praise of Clark Kent: Creative Metacognition and the Importance of Teaching Kids When (Not) to Be Creative. *Roeper Review, Vol. 35*, Issue 3. Available online: https://doi.org/10.1080/02783193.2013.799413

Kaufman, J. C., Evans, M. L. & Baer, J. (2010). The American Idol Effect: Are Students Good Judges of Their Creativity across Domains? *Empirical Studies of the Arts, Vol. 28*, Issue 1, pp. 3-17. Available online: https://doi.org/10.2190/EM.28.1.b

Kaufman, J.C. & Baer, J. (Eds.). (2005). *Creativity across domains: Faces of the muse*. Mahweh, NJ: Lawrence Erlbaum.

Kaufman, J. C. & Beghetto, R. A. (2009). Beyond Big and Little: The Four C Model of Creativity. *Review of General Psychology, American Psychological Association, Vol. 13*, No. 1, pp. 1–12.

Kember, D. Hong, C., Yau, V. & Ho, A. (2014). Is it the teaching or the discipline? Influences of disciplinary epistemology and pedagogy on students adapting study behaviour and epistemological beliefs. *European Journal of Higher Education, Vol. 4*, Issue 4, pp. 348-362. Available online: https://doi.org/10.1080/21568235.2014.930794

Kinman, G. & Wray, S. (2013). *Higher stress: A Survey of Stress and Well-Being among Staff in Higher Education*. University and College Union. Available online: https://www.ucu.org.uk/media/5911/Higher-stress-a-survey-of-stress-and-well-being-among-staff-in-higher-education-Jul-13/pdf/HE_stress_report_July_2013.pdf

Krause, K-L, D. 2012. Challenging perspectives on learning and teaching in the disciplines: the academic voice. *Studies in Higher Education, Taylor & Francis, Vol. 39*, Issue 1, pp. 2-19. Available online: https://doi.org/10.1080/03075079.2012.690730

Lennox, P., Wilson, C., & Brown, M., (2016). *Creative Inhibition: How and Why,* in *Creativity in Arts, Science and Technology,* KIE Conference Book Series, Ed. Prof. F. Reisman.

Lindholm-Romantschuk, Y. (1998). *Scholarly book reviewing in the social sciences and humanities. The flow of ideas within and among disciplines.* Westport, Connecticut: Greenwood Press.

Livingston, L. (2010). Teaching Creativity in Higher Education. *Journal of Arts Education Policy Review, Taylor & Francis, Vol. 111*, Issue 2, pp. 59-62.

Ludovice,P. J., Lefton, L. E. & Catrambone, R. (2010). *Improvisation for Engineering Innovation*. American Society of Engineering Education National Meeting, Louisville, KY, June 2010. Available online: http://www.appliedhumor.com/resources/ASEE1.pdf

Mann, D.L. (2000). *The Four Pillars of TRIZ*. Invited paper at International Design Conference, Brunel, June 2000.

Marquis, E. & Vajoczki, S. (2012). Creative Differences: Teaching Creativity Across the Disciplines. *International Journal for the Scholarship of Teaching and Learning, Vol. 6*, No. 1, Article 6. Available at: https://doi.org/10.20429/ijsotl.2012.060106.

McKay, A. S., Karwowski, M. & Kaufman, J. C. (2017). Measuring the muses: Validating the Kaufman Domains of Creativity Scale (K-DOCS). *Psychology of Aesthetics, Creativity, and the Arts, Vol 11(2)*, May 2017, pp. 216-230.

Murdock, M. C. (2010). The Effects of Teaching Programmes Intended to Stimulate Creativity: A disciplinary view. *Scandinavian Journal of Educational Research, Vol. 47*, Issue 3, pp. 339-357. Available online: https://www.tandfonline.com/doi/abs/10.1080/00313830308597?journalCode=csje20

National Academy of Engineering (2004). *The Engineer of 2020: Visions of Engineering in the New Century.* National Academies Press, 500 Fifth Street, N.W., Lockbox 285, Washington, D.C. Available online: https://www.nap.edu/read/10999/chapter/1

Oreilly, J. (Sir) (2014). *STEAM ahead for growth: Knowledge, innovation and industrial strategy*. IET Mountbatten Memorial Lecture, 20th November.

QAA Subject Benchmark Statements for subjects studies at undergraduate degree level: http://www.qaa.ac.uk/assuring-standards-and-quality/the-quality-code/subject-benchmark-statements/honours-degree-subjects
QAA (2016a) Subject Benchmark Statement for Music: http://www.qaa.ac.uk/en/Publications/Documents/SBS-Music-16.pdf

QAA Subject Benchmark Statement for Engineering (2016b): http://www.qaa.ac.uk/en/Publications/Documents/SBS-engineering-15.pdf

Perry, T. S. (2017). *The Engineers of the Future Will Not Resemble the Engineers of the Past: It's time for a new breed of engineer, former Stanford dean tells IEEE leaders and honorees at first IEEE Summit.* IEEE Spectrum. Available online: https://spectrum.ieee.org/view-from-the-valley/at-work/education/the-engineers-of-the-future-will-not-resemble-the-engineers-of-the-past

Pretz, J. E. & McCollum, V. A. (2014). Self-perceptions of creativity do not always reflect actual creative performance. *Psychology of Aesthetics, Creativity, and the Arts, Vol 8(2)*, May 2014, pp. 227-236.

Pryor, J. & Crossouard, B. Formative assessment – reconceptualizing disciplinary practices, identities and pedagogies? John Pryor and Barbara Crossouard, University of Sussex SRHE paper number: 0173 (Symposium 1401) Centre for Higher Education and Equity Research (CHEER), University of Sussex, UK: https://www.sussex.ac.uk/webteam/gateway/file.php?name=john-pryor-and-barbara-crossouard-paper---formative-assessment.pdf&site=41

Read, A. & Petocz, P. (2004). Learning domains and the process of creativity. T*he Australian Educational Researcher, Volume 31*, Issue 2, pp. 45–62. Available online: https://link.springer.com/article/10.1007/BF03249519

Repp, C. (2012). What's Wrong with Didacticism? *The British Journal of Aesthetics*, *Vol. 52*, Issue 3, 5 July 2012, pp. 271–285, https://doi.org/10.1093/aesthj/ays023.

Rowlands, S. (2011). Disciplinary Boundaries for Creativity. *Journal of Creative Education 2011. Vol. 2*, No. 1, pp. 47-55. Available online: www.researchgate.net/profile/Stuart_Rowlands/publication/228475200_Discussion_Article_Disciplinary_Boundaries_for_Creativity/links/53db7a260cf2631430cb502e.pdf

Royal Academy of Engineering. (2016). How to Solve the Engineering Skills Crisis. *Spectator Magazine*, 16th November 2016. Available online: https://www.spectator.co.uk/2016/11/how-to-solve-the-engineering-skills-crisis/

Sala, G. & Gobet, F. (2017). When the music's over. Does music skill transfer to children's and young adolescents' cognitive and academic skills? A meta-analysis. Elsevier, *Educational Research Review, Vol. 20*, pp. 55-67. Available online: https://doi.org/10.1016/j.edurev.2016.11.005

Shuttleworth, S. (2018). *Our disciplines are disappearing, we need to act now.* WONKHE. Available online: https://wonkhe.com/blogs/our-disciplines-are-disappearing-we-need-to-act-now/

Simonton, D. K. (2017). Varieties of (Scientific) Creativity: A Hierarchical Model of Domain-Specific Disposition, Development, and Achievement. *Perspectives on Psychological Science, Vol. 4*, Issue: 5, pp. 441-452. Available online: https://doi.org/10.1111/j.1745-6924.2009.01152.x

Smith, R. A. ed. (1991). *Innovative Teaching in Engineering*. Ellis Horwood Limited.

Stano, M. T. & Vieira, F. (2014). *Pedagogy at university in transition: reflections from the Bologna Process and the voices of pedagogical managers in Engineering courses in Portugal.* Rev. Diálogo Educ., Curitiba, v. 14, n. 42, pp. 605-628. Available online: http://dx.doi.org/10.7213/dialogo.educ.14.042.AO05

Sternberg, R. (2006). The Nature of Creativity. *Creativity Research Journal, Taylor & Francis, Vol. 18*, pp. 87-98. Available online: https://doi.org/10.1207/s15326934crj1801_10

Sternberg, R. J. & Lubart, T. I. (2002). Investing in Creativity. *American Psychologist, 51*(7), pp. 677-688. American Psychological Association. Available online: http://dx.doi.org/10.1037/0003-066X.51.7.677 https://www.montclair.edu/media/montclairedu/csam/cmsproject/investing-creativity.pdf

T-Academy. (2018). *What is the "T"?* Michigan State University: http://tsummit.org/t
Twenty thousand per annum shortfall of engineering graduates in the UK alone (Engineering UK, 2017): https://www.engineeringuk.com/media/1356/enguk_report_2017_synopsis.pdf

Walker, D. & Nocorine, N. (2007). Boundary-Crossing Competence: Theoretical Considerations and Educational Design. *Journal of Mind, Culture, and Activity, Taylor & Francis, Vol. 14*, Issue 3. Available online: https://doi.org/10.1080/10749030701316318.

Ward, T. B., Smith, S. M. & Finke, R. A., in Sternberg, R. J. ed. (1999). *Handbook of Creativity*. Cambridge University Press.

Wastl-Walter, D. ed. (2011). *The Ashgate Research Companion to Border Studies*. Routledge. Taylor & Francis group: London & New York.

Wilson, C., & Brown, M. (2016). Staying Creative: Creative Technique, Habit, and Experience, in *Creativity in Arts, Science and Technology,* KIE Conference Book Series, Ed. Prof. F. Reisman.

Wilson, C. & Brown, M. (2014). The Business of Invention: Considering Project Management in the Arts and Industry, in Reisman, F, K., ed., *Creativity in Business,* KIE Conference book series: ISBN 978-1-85924-296-4.

Wilson, B. G. (1996). *Constructivist Learning Environments: Case studies in instructional design*. Educational Technology Publications. Englewood Cliffs, New Jersey.

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B. & Wesslén, A. (2012). *Experimentation in Software Engineering*. Springer, Science & Business Media.

World Economic Forum. (2016). *The Future of Jobs Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution.* Available online: http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf

Zbainos, D & Anastasopoulou, A. (2012). Creativity in Greek Music Curricula and Pedagogy: An Investigation of Greek Music Teachers' Perceptions. *Journal of Creative Education, Vol. 3*, No. 1, pp. 55-60. Available online: http://dx.doi.org/10.4236/ce.2012.31009

CHAPTER FOUR

DIGITAL CREATIVE PROBLEM SOLVING: THE BEYONDERS PROGRAM

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Abstract

Though interest in STEM/STEAM is increasing as a component of k12 education, the connection of STEM/STEAM to such critical 21^{st} century skills as creative thinking remains unclear. Does increasing focus on STEM/STEAM diminish the opportunities for students to exercise their creativity? Or might STEM/STEAM open new avenues for creativity to be promoted within the k12 classroom? This chapter will explore the concept of STEM/STEAM in reference to 21^{st} century learning skills. The specific skills that will be addressed are creativity and innovation, digital learning, creative problem solving, collaboration and communication. Discussion of a pilot digital creative problem solving program, the Beyonders Program, will be included, along with preliminary research into the impact of this program. The Beyonders Program includes a pre/post creativity assessment along with team challenges for secondary students. We conclude that focus on STEM/STEAM as a component of creative problem solving offers new opportunities to increase student creativity and other 21^{st} century skills.

STEM/STEAM

The National Science Foundation developed the acronym of STEM for science, technology, engineering and mathematics. STEM is an inquiry-based approach that incorporates teamwork and instruction in the "soft skills" needed for business and industry (The Partnership for 21^{st} Century Skills, 2007). In addition, STEM is an integrative approach to curriculum and instruction that attempts to remove boundaries between subjects (Morrison & Bartlett, 2009). In this way, STEM acts as a transdisciplinary vehicle for overcoming the compartmentalized disciplinary approach to education (Holley, 2009).

Indeed, in terms of this key transdisciplinary element of STEM, recent innovative thinking in STEM disciplines has relied on breaking down the distinction between disciplines traditionally seen as "creative" like the arts or music and STEM disciplines traditionally seen as more rigid or logical-mathematical (Catterall, 2002; Henriksen, 2014). For example, the art element (A) of STEAM is often referred to as creativity in education (Land, 2013; Sousa & Pilecki, 2013). Art has proved to be a valuable instructional tool for integrating STEM into the regular curriculum as well as engaging students in the social and cultural contexts of science and technology. (Kuhn, Greenhalgh & McDermott, 2016). The involvement of the arts provides a more complete knowledge and skill base for learners to develop the most effective solutions possible.

As such, STEAM is an essential paradigm for creatively infused teaching and learning in STEM disciplines. The concept of STEAM suggests a need to celebrate and encourage the development of creativity by allowing students to use original and artistic ways to express knowledge (Barber, King & Buchanan, 2015).

There are a number of K-12 STEAM programs. Characteristics of quality STEM/STEAM programs include (Jolly, 2014):

1. The context is motivating, engaging, and real world.
2. Students integrate and apply meaningful and important mathematics and science content.
3. Teaching methods are inquiry based and student centered.
4. Students engage in solving challenges using a problem solving process.
5. Teamwork and communications are a major focus. Throughout the program, students have the freedom to think critically, creatively, and innovatively, as well as opportunities to fail and try again in safe environments.

According to Turner (2013), STEM/STEAM education is not just an area of study, but it is also a way of teaching and learning that is problem/project-based, collaborative, and focused on solving real- world problems. STEM/ STEAM programs educate the whole student, emphasizing innovation, problem solving, critical thinking, and creativity. Oner, et al (2016) found that secondary students believe that STEM careers require creativity.

As such, the very structure of STEM/STEAM programs, especially their integrative approach to learning, suggests an important opportunity for even greater conscious focus on promoting creative thinking in the classroom. Utilizing creativity can establish the interdisciplinary concepts found in STEM in addition to engaging students in learning. In addition, creativity can serve as a means for students to express their understanding of STEM content. Indeed, according to Boy (2013), creativity cannot be treated separately from STEM, and Mote, Strelecki & Johnson (2014) note that the use of creativity in STEM activities has grown.

The benefits of consciously applying creative thinking to a STEM based curriculum are many., Students apply previously learned information to creatively address a problem that they have not previously encountered (Roberts, 2012). Students involved in integrated problem-solving curriculum display increased engagement, satisfaction and enjoyment (Havice, 2009). Teachers agree that students are more engaged in learning when one or more creative modalities are included (Gullatt, 2007). Taken together, STEM and a conscious focus on creativity in the classroom offer a potent combination to improve educational outcomes and better prepare students for 21st century occupations.

Creativity and Innovation

Creativity is a vital ingredient in meeting the challenges of a continuous life cycle, a cycle in which growth and change are the norm from conception throughout life. A life filled with growth and change requires a conscious effort to think creatively. To develop creativeness, the mind needs to be exercised as well as filled with materials out of which ideas can be formed. The richest fuel for ideation is firsthand experience (Osborn, 1963). Anytime one is faced with a problem or dilemma with no learned or practiced solution, some creativity is required (Torrance, 1962;1988;1995). In the 2010 IBM Global study of 1,500 CEO's, creativity was selected as the most crucial factor for future success.

Fostering creativity in educational activities is vital. Research demonstrates that activities requiring creative thinking results in positive outcomes (Oner, et al, 2016). Problem and team based learning provide opportunities for student to develop their creativity, engage in collaborative learning and increase advanced thinking skills (Hargrove, 2011).

Creativity and innovation are linked with the purpose of producing something of value that can be traded, developed and commercially exploited. Innovation is the application of a creative solution with a profitable outcome (Serrat, 2017).

E. Paul Torrance

Dr. E. Paul Torrance was a pioneer in creativity research and education for more than 60 years. He produced over 1800 publications and presentations on creativity (Millar, 1997). Torrance chose to define creativity as a process because he thought if the creative process could be used to predict what kinds of person could master the process, what kind of climate makes it grow and what products would be involved (Torrance, 1995). Torrance created a battery of tests of creative thinking abilities for use from kindergarten through graduate and professional education. The *Torrance Tests of Creative Thinking* (TTCT) (1966) are the most widely used assessments of creative talent in the United States and have been translated into over 50 different languages.

Torrance (1979) found that learning and thinking creatively takes place in the process of sensing difficulties, problem, gaps in information; making guesses or formulating hypotheses about these deficiencies; in testing these guesses and possibility, revising and retesting them; and finally in communicating the results. Vital human needs are involved in each of these four stages.

Creative Problem Solving

Torrance's research demonstrates that a variety of techniques for training in creative problem solving produce significant creative growth without interfering with traditional kinds of educational achievement. Creative growth seems to be the greatest and most predictable when deliberate, direct teaching of creative thinking skills are involved (Torrance, 1995).

Caswell (2006) describes it as an approach to finding workable answers to problems that exist in real life. Creative problem solving skills operate at the most general level and can influence performance in any domain (Amabile, 1989). Problem solving activities shift the focus of the class to a student centered orientation that provides a more creative and interactive environment of engagement (Yen & Lee, 2011). These skills can be influenced by training and by experience. Torrance (1957) found that elements of a creative solution can be taught, but the creativity itself must be self-discovered and self-disciplined.

There is a big difference between getting ideas and doing something about them. An idea all by itself is nice, but doesn't mean much unless it's attached to people and things. The value of ideas comes when they are applied. In creative problem solving, students work in groups to creatively solve a problem or issue that generally has no known or predetermined solution (Caswell, 2006). Creative problem solving is a teaching method that incorporates active learning strategies to engage students in working with complex situations (Samson, 2015).

A key way to engage students is to integrate active learning strategies into the curriculum (Delialioglu, 2011; Hayden, Ouyand, Scinski, Ollsterwski $ Bielefeldt, 2011). Active learning strategies that incorporate student collaboration that are challenging with timely feedback help increase both learning and academic achievement (Delialioglu, 2011). Creative problem solving is an effective strategy to motivate and engage students in learning. It promotes deeper learning and fosters the development of effective problem solving and critical thinking skills (Samson, 2015).

Problem Based Learning

PBL is an instructional and curricular, learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem (Savery, 2006). It is an approach that enables students to learn while actively examining meaningful problems (Yew & Goh, 2016).

Hmelo-Silver (2004) described PBL as an instructional method in which students learn through facilitated problem solving that centers on a complex problem that does not have a single correct answer. Students work in collaborative groups to identify what they need to learn in order to solve a problem, engage in self-directed learning, apply their new knowledge to the problem, and reflect on what they learned and the effectiveness of the strategies employed. (Savery, 2006, p. 12)

PBL fosters the ability to identify the information needed for a particular application, where and how to seek that information, how to organize that information in a meaningful conceptual framework, and how to communicate that information to others. (Duch, Groh, & Allen, 2001, pp. 6-7). PBL teaching methods increase the creative thinking skills of students (Ersoy & Baser, 2014).

Problem-based learning is differentiated from traditional, lecture-based instruction by employing a real-world problem that engages the learner in active exploration rather than providing the learner with passive reception of lecture material (Peterson, 2004). The underlying assumption is that through the process of engaging with the real-world problem the learner learns.

Deslauriers et al (2011) confirmed that students become enthusiastic when experiencing problem-based learning (PBL). Studies of applied problem-based learning in online environments indicate that learners develop higher-order thinking skills such as creative and critical thinking and also have more motivation to participate and became more active learners (Şendağ & Odabaşı, 2009; Delialioğlu, 2012).

Collaboration and Communication

Collaboration is about shared meaning and vision. It is a purposeful relationship formed to solve a problem, to create, discover, change or to review something. Collaboration involves sharing responsibilities; it involves each team member being equal and contributing to the process. According to Sawyer (2007, p.7), collaboration drives creativity because innovation always emerges from a series of sparks – never a single flash of insight. Students learn about themselves in collaborations. They learn to identify each other's strengths and talents as well as increase self-esteem by sharing and achieving a common goal.

Positive outcomes from a collaborative learning environment include:

1. increased levels of achievement
2. tend to feel better about themselves when given opportunities for success and self-expression
3. learn to deal with differences and to show respect by acknowledging contributions of all group/team members
4. learn to recognize each other's strengths by communicating their experiences and ideas
5. gain practical experiences in dealing with people who are culturally, academically or physically different from themselves which enables

students to more readily accept difference in and outside of the classroom

Collaboration is a core concept for creativity that requires expertise in a wide range of domains (Karakaya & Demirkan, 2015). As an innovative activity, team members engage in a shared process of exploration. Collaborative learning is the joint construction of shared meaning, understanding and knowledge, based on elaboration and evaluation of group members' ideas and thoughts (Chen, Gao, Yan & Xu, 2015).

Creativity is a collaborative process in which the members of the team produce a new and useful output for the group or wider community (Chen, Gao, Yan & Xu, 2015). When learning in teams, students interact with their peers with effective communication (Morrison et al., 2009). During the collaboration process, students not only learn to respect each other, they also develop self-regulation in order to contribute to the project tasks (Kuo et al., 2012; Trilling and Fadel, 2009).

Communication is an essential part of creativity. Once a solution is found the creators are compelled to communicate it. Creativity is the "c" in communication (Boy, 2013). In order to collaborate, there must be communication and if there is good communication, the collaboration will flourish and lead to more productive and creative solutions. The quality and amount of communication among team members is an effective assessment of the success of a collaboration (Shen, Ony & Nee, 2010).

Technology

21st century and problem-based learning skills include the development of creativity, self-motivation, innovation, problem-solving and collaboration skills (Kaufman, 2013). The three factors of problem based learning, authentic assessment and meaningful community are a powerful combination of tools that online instructors can use to provide students with effective digital pedagogy (Barber, King & Buchanan, 2015).

Without creativity, the process of developing technological solutions to the problems we face in society is limited to the replication of old solutions (Cropley, 2015). In order to find the new solutions that are capable of solving new and old problems, creativity is required (Torrance, 1995).

Digital technologies can be utilized to create a new type of cyberlearning environment—an environment that effectively targets creative thinking and problem solving within the classroom. They may hold the unique potential to be replicated and extended across the globe in a cost-effective and wide-ranging manner. The impact of such a digital environment may be transformative in the classroom and bring a wider range of higher-level thinking skills to a global population.

Technology-rich activities can sustain high levels of student engagement and peer collaboration compared to less technology focused activities (West, 2013).

Jonassen (2000, 2005) and others have identified the effective use of technology in supporting creativity and problem solving. Such technology includes what are often referred to as Mindtools.

Jonassen's research suggests that Mindtools play an important role in promoting the problem solving capacities of students, providing a fertile environment for student engagement and cognitive growth. The technologies that Jonassen and others identify, however, are not new creativity tools, nor are they technologies that focus specifically on the human creative process. Rather, such tools are often existing software applications, such as spreadsheets, database programs, mind-mapping programs, and so on, that teachers may attempt to use with students in new ways. While certainly of great value in the classroom, such technologies are inherently limited in their ability to promote and assess creative outcomes, as their focus and design does not directly target creative thinking and problem solving.

In addition to Mindtools, some K-12 educators are now experimenting with existing online technologies—especially collaborative software—to promote creative activities in the classroom. Indeed, the growing desire for new web-based collaborative tools is perhaps best illustrated with the increasing use within the K-12 classroom of such social networking sites and applications as Facebook, Twitter, Instagram, Second Life, and Google Docs.

While allowing for valuable new forms of interaction and information-sharing in and outside of the classroom, such software programs are again severely limited by their designed uses and applications. Such programs are primarily intended to allow users to share existing information—not develop, construct, evaluate, and actualize new creative ideas and innovative artifacts.

Beyonders Program

The Beyonders Program is a mobile application developed to better understand and promote the creative process within and beyond the classroom. The Beyonders Program draws together a number of activities directly connected to research and education, with a stated goal of creating a digital creativity system focused squarely on teaching, training and learning. Specifically, the Beyonders Program seeks to:

- apply existing research of human creativity to create a comprehensive digital creativity application
- promote the teaching, practice and assessment of creativity in the classroom
- train teachers to use the Beyonders Program creativity tools

- promote research into effective creativity models, problem solving, and higher-order cognition
- promote research into information technology and advanced web technologies that might be effectively used in creating cyber creativity environments
- develop digital tools to store and track development of student creativity

The value of mobile devices is that they allow students to connect, communicate, collaborate and create using rich digital resources (West, 2013). The Beyonders Program offers groups a comprehensive CPS-based mobile app that utilizes personal tablets for accessing the exercises and projects in the classroom, at home and in the community. The Program provides an immersive digital learning environment that consciously seeks to keep students linked, digitally and figuratively, to active learning throughout the day, in and beyond the traditional classroom.

The Beyonders Program offers participating students the ability to collaborate on assignments and projects, creating what the program refers to as virtual “pop-up classrooms.” Sixty one percent of high school students surveyed thought that collaborating with classmates on real world problems would help them be more successful in science, for example (Project Tomorrow Speak Up Survey, 2013).

Through the Beyonders Program, students participate in activities of scientific investigation and technical design of real world problems, becoming the main investigators and questioners. Investigation, creative thinking and problem solving are central to science and technology education—they are also precisely the skills that the Beyonders program seeks to promote in grades 6-12 classrooms worldwide.

A growing body of research supports the efficacy of inquiry-based learning on student motivation and engagement (Jonassen, 2011) and student retention and graduation rates (Dynarski et. al, 2008; Kemple and Snipes, 2000). For substantive improvements in student retention and learning outcomes to appear in U.S. classrooms, it is imperative that schools offer authentic learning opportunities that connect classrooms with the broader community. Engaging in 21st century thinking skills like creativity, decision-making, and collaboration must be authentic and meaningful to students, especially as they relate to the workplace.

Beyonders Pilot Research

The term Beyonders is meant to designate individuals in society who exhibit advanced creativity—individuals who move beyond others in terms of the development and application of advanced creative thinking and problem solving abilities (Torrance, 2002). The main goals of the Beyonders Program are:

(1) To engage students in STEM-based, real-world creative problem solving projects using advanced digital technology (Problem-Based Learning).

(2) To develop the creative capacities of 6^{th}-12^{th} grade students so that they realize their abilities to realize creative outcomes and initiate positive individual and social change (21^{st} Century Thinking Skills Development).

(3) To systematically research the creative capacities of 6^{th}-12^{th} grade secondary school students before and after participation in the Beyonders Program (Advanced Skills Assessment).

The Beyonders Program is a digital education and research program for secondary students. This on-line, program offers 4 distinct challenges to participants during an academic year. These STEM related challenges include such topics as entrepreneurship, environmental awareness, inventing, improved health, community safety and improvement, etc. Students are introduced to creative problem solving models that are applied to a range of local and global issues. Teams of students are asked to develop creative solutions and to take action to communicate their solutions. Each challenge is developed and evaluated by trained scorers.

The Beyonders Program provides teams with opportunities to work with students from other regions and countries on global challenges. The Beyonders platform provides synchronous and asynchronous communication tools to facilitate discussions between team members as they work through the provided challenges.

A pilot of the Beyonders Program was conducted during the 2014-2015 school year at a residential treatment program for troubled adolescent boys ages 11-18. The students were pre and post tested using the VCAI-re (VAST Creative Abilities Indicator - research edition). They participated in 28 one-hour per week sessions, during school hours, between assessments.

73% of the TBH boys (N=27) realized an increase in their creativity scores. The average gain for overall test scores was 17.3 points, an 85% increase between pre and post testing. Overall, the greatest scoring gains were for Fluency (87% gain), Originality (170% gain), Elaboration (81% gain) and Creative Strengths (78% gain). Flexibility showed little difference between Pre and Post testing.

The SPSS results indicated significant increases ($p<.05$) in fluency, originality, elaboration and overall creativity as cited in the tables that follow.

Paired Samples Statistics

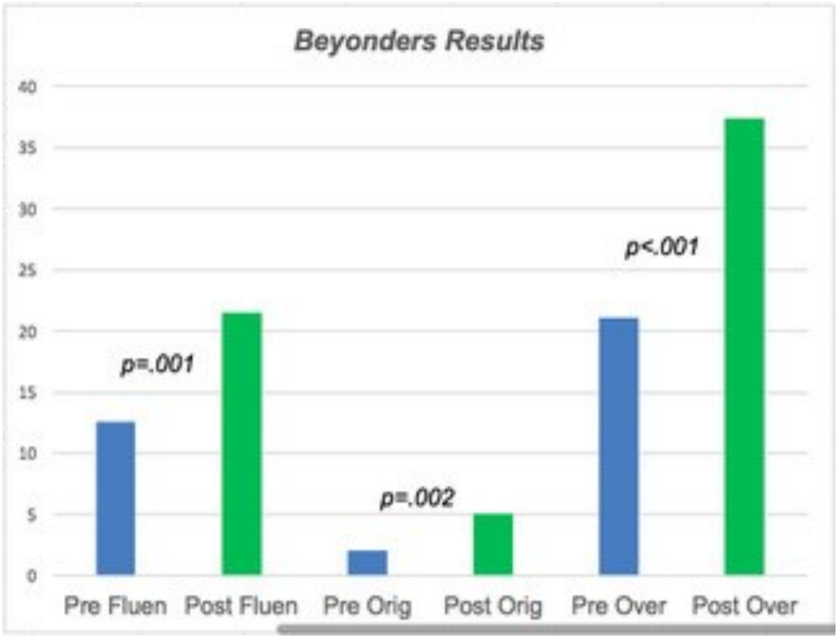
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre_Flue	11.63	27	8.858	1.705
	Post_Flue	21.56	27	8.460	1.628
Pair 2	Pre_Flex	1.07	27	1.035	.199
	Post_Flex	.78	27	1.188	.229
Pair 3	Pre_Orig	1.93	27	3.257	.627
	Post_Orig	4.89	27	5.191	.999
Pair 4	Pre_Elab	2.78	27	3.620	.697
	Post_ Elab	5.52	27	5.243	1.009
Pair 5	Pre_CS	2.15	27	3.072	.591
	Post_CS	3.85	27	4.035	.777
Pair 6	Pre_Over	19.56	27	14.577	2.805
	Post_Over	36.59	27	16.967	3.265

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre_Flue & Post_Flue	27	.040	.844
Pair 2	Pre_Flex & Post_Flex	27	.108	.593
Pair 3	Pre_Orig & Post_Orig	27	.598	.001
Pair 4	Pre_Elab & Post_ Elab	27	.170	.395
Pair 5	Pre_CS & Post_CS	27	.238	.233
Pair 6	Pre_Over & Post_Over	27	.258	.193

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Pre_Flue - Post_Flue	-9.926	12.003	2.310	-14.674	-5.178	-4.297	26	.000
Pair 2	Pre_Flex - Post_Flex	.296	1.489	.287	-.293	.885	1.034	26	.311
Pair 3	Pre_Orig - Post_Orig	-2.963	4.165	.801	-4.610	-1.315	-3.697	26	.001
Pair 4	Pre_Elab - Post_ Elab	-2.741	5.841	1.124	-5.052	-.430	-2.438	26	.022
Pair 5	Pre_CS - Post_CS	-1.704	4.453	.857	-3.465	.058	-1.988	26	.057
Pair 6	Pre_Over - Post_Over	-17.037	19.302	3.715	-24.673	-9.401	-4.586	26	.000



Although this is a very limited study, it does provide encouraging data for continued research and application.

Team Based Learning

Team-based problem solving is a popular and established method of promoting creative thinking among students and has, in the past, served as the basis for a number of successful creativity programs, including Odyssey of the Mind, Destination Imagination, Future Problem Solving, and TASC. Such programs, while certainly important and effective among their target student populations, have seemingly suffered from a number of flaws inherent in their deployment models and methods. Such flaws have limited the acceptance and use of such programs as means of promoting creative thinking, even given their admirable goals of promoting higher-order thinking among participants.

Specifically, many existing creativity programs: (i) have been geared heavily toward the gifted and talented population, neglecting the wider student population, especially the under-represented and disadvantaged; (ii) have often focused on single conceptualizations of creativity and one basic problem solving model, thereby limiting their application to different curriculum areas and issues, as well as teacher and student needs; (iii) have not sought to evaluate nor gather research on the impact of their creativity tools in order to better understand the creative process and the particular tools needed to promote human creativity and its products; (iv) have been designed to focus on predetermined topic areas, usually determined by the supplying organization itself—usage within the classroom has therefore been limited; (v) have often been created for use outside of the standard classroom curriculum and have therefore provided little focus on ways of applying creativity tools within the classroom; (vi) have usually charged fees to participating students and teams for program access (given their extracurricular nature), further limiting their use and application among the broader student population, especially the disadvantaged; (vii) have not developed a technological component to promote creativity in the K-12 classroom, nor do they currently envision technology as playing an integral role in promoting human creativity and its products in the future.

The Beyonders Program shares with such programs the underlying goals of encouraging creative thinking and problem solving skills among students. Given its focus on flexible digital technologies, however, the Beyonders Program offers a distinctly different set of methods for promoting and assessing human creativity and its outcomes in the classroom.

Conclusion

Creativity is learning by doing. Collaboration facilitates both solving creative tasks and the development of creativity (Doppenberg, den Brok & Bakx, 2012). Experimentation leads to creativity. Problem based learning arouses students' curiosity and sparks their creative imaginations and critical thinking (Capon & Kuhn, 2004). Embracing and institutionalizing mobile technology can transform learning (West, 2013).

Students of today—our future inventors, producers, and leaders—will be called upon to explore a host of issues in new ways, evaluate numerous competing ideas, and generate innovative solutions to a variety of unique challenges and situations. The development of more effective, advanced thinking abilities is key to preparing students for competitive and innovation based environments.

Digital technologies present a unique opportunity for schools worldwide to answer the growing need for creative thinking and innovative activities.

References

Amabile, T. M. (1989). Growing up creative. NY: Crown Publishers
Barber, W., King, S., & Buchanan, S. (2015). Problem based learning and authentic assessment in digital pedagogy: Embracing the role of collaborative communities. The Electronic Journal of e-Learning, 13(2), 59-67.

Boy, G. A. (2013). From STEM to STEAM: Toward a human centered education. Paper submitted to the European Conference on Cognitive Ergonomics, Toulouse, France.

Capon, N. & Kuhn, D. (2004). What is so good about problem-based learning. Cognition and Instruction, 22(1), 61-71.

Caswell, D. (2006). Creative problem-solving. London: Society for Teaching and Learning in Higher Education.

Catterall, J. S. (2002). The arts and the transfer of learning. In R. J. Deasy (Ed.). Critical links: Learning in the arts and student academic and social development. Washington, DC: Arts Education Partnership.

Chen, J., Gao, X., Yan, L., & Xu, D. (2015). Recent progress, opportunities and challenges in collaborative learning and orchestrating creativity. World Scientific News, 9, 112-131.

Cropley, D. H. (2015). Promoting creativity and innovation in engineering education. Psychology of Asthetics, Creativity and the Arts, 9(2), 161-171.

Delialioglu, O. (2011) . Student engagement in blended learning environments With lecture-based and problem-based instructional approaches. Educational Technology of Society, 15(3), 310-322.

Deslauriers, L, Schelew, E. and Wieman, C. (2011). Integrated learning in a large-enrollment physics class. Science, 332(6031), 862-864D

Doppenberg, J. J., den Brok, P. J., & Bakx., A.W.E.A. (2012). Teaching and Teacher Education, 28, 899-910).

Duch, B. J., Groh, S. E., & Allen, D. E. (Eds.). (2001). The power of problem-based learning: A practical "how to" for teaching undergraduate courses in any discipline. Sterling, VA: Stylus.

Dynarski, M., Clarke, L., Cobb, B., Finn, J., Rumberger, R., & Smink, J. (2008). Dropout Prevention. IES Practice Guide. NCEE 2008-4025.

National Center for Education Evaluation and Regional Assistance.
Ersoy, E. & Baer, N. (2014). The effects of problem-based learing method in higher education on creative thinking. Procedia – Social and Behaviorial Sciences, 116, 3495-3498.

Gullatt, D. E. (2007). Research links the arts with student academic gains. The Educational Forum, *71*(3), 211-220.

Hargrove, R. (2011). Fostering creativity in the design studio: A framework towards effective pedagogical practices. Art, Design & Communication in Higher Education, 10(1), 7-31.

Havice, W. (2009). The power and promise of a STEM education: Thriving in a Complex technological world. IN ITEEA (Ed.). The Overlooked STEM Imperative: Technology and Education (pp.10-17). ITEEA.

Hayden, K., Ouyand, Y., Scinski, L., Ollsterwski, B., & Bielefeldt, T. (2011). Increasing student interest and attitudes in STEM: Professional development and activities to engage and inspire learners. Contemporary Issues in Technology and Science Teacher Education, 11 (1), 1-22.

Henriksen, D. (2014). Full STEAM ahead: Creativity in excellent STEM Teaching Practices. The STEAM Journal, 1(2), Article 15.

Hmelo-Silver CE. (2004). Problem-based learning: What and how do students learn? Eductional Psychology Review,16(3), 235–266.

Holley, K. M. (2009). Understanding interdisciplinary challenges and opportunities in higher education. ASHE Higher Education Report, 35(2), 1-131.
Jolly, A. (2014). STEM vs STEAM: Do the arts belong? Education Week Teacher, 1-3. (http://www.edweek.org/tm/articles/2014/11/18/ctq-jolly-stem-vs-steam.html?tkn=QSXDkiTUr5UfZ0BeGJgEKqj1cjIw3Ujm3PY9&print=1)

Kuhn, M., Greenhalgh, S., & McDermott, M. (2016). Using creativity from art and engineering to engage students in science. Journal of STEM Arts, Crafts and Constructions, 1(2), 9-15.

Kuo, F.R., Hwang, G.J. and Lee, C.C. (2012) 'A hybrid approach to promoting students' web- based problem-solving competence and learning attitude', *Computers & Education*, Vol. 58, No. 1, pp.351–364.

Jonassen, D. H., & Carr, C. S. (2000). Mindtools: Affording multiple knowledge representations for learning. Computers as cognitive tools, *2*, 165-196.

Jonassen, D., Strobel, J., & Gottdenker, J. (2005). Model building for conceptual change. *Interactive Learning Environments*, *13*(1-2), 15-37.

Jonassen, D. H. (2011). Design Problems for Secondary Students. *National Center for Engineering and Technology Education.*

Karakaya, A. F. & Demirkan, H. (2015). Collaborative digital environments to enhance the creativity or designers. Computers in Human Behavior, 42. 176-186.

Kaufman, K. (2013). 21 Ways to 21st century skills: Why students need them and ideas of practical implementation. Kappa Delta Pi Record, 49(2), 78-83.

Kemple, J. J., & Snipes, J. C. (2000). Career Academies: Impacts on Students' Engagement and Performance in High School.

Kiili, K. (2005). Digital game based learning: Towards an experiential gaming model. Internet and Higher Education, 8, 13-24.

Kolb, D. (1984).Experiential learning: Experience as the source fo learning and development. New Jersey: Prentice Hall

Land, M. H. (2013). Full STEAM ahead: The benefits of integrating the arts into STEM, Procedia Computer Science, 20, 547-552.

Millar, G. (1997). E. Paul Torrance – "The Creativity Man": An authorized Biography. Norwood, NJ: Ablex Publishing Co.

Morrison, J. & Bartlett, B. (2009). STEM as a curriculum: An experimental approach. Retrieved from http://www.lab- aids.com/docs/stem/ EdWeekArticleSTEM.pdf

Mote, C., Strelecki, K. & Johnson, K. (2014). Cultivating high-level organizational engagement to promote novel learning experiences in STEAM. The STEAM Journal, 1(2), 1-9.

Oner, A. T., Nite, S., B., Capraro, R. M. & Capraro, M. M. (2016). From STEM to STEAM: Students' beliefs about the use of their creativity. The STEAM Journal, 2(2), Article 6.

Osborn, A. (1963). Applied imagination (3rd edition). NY: Charles Scribner's.

Peterson, T. O. (2004). So you're thinking of trying problem based learning? Three critical success factors for implementation. Journal of Management Education, 28(5), 630-647.

Project Tomorrow Speak Up Survey, "From Chalkboard to Tablets: The Emergence of the K-12 Classroom", April, 2013

Roberts, A. (2012). A justification for STEM education. Technology and Engineering Teacher. 3, 1-5.

Samson, P. L. (2015). Fostering student engagement: Creative problem-solving in small group facilitations. Collected Essays on Learning and Teaching, 8 , 153-164.

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. Interdisciplinary Journal of Problem-Based Learning, 1(1), 9-20.
Sawyer, K. (2007). Group genius. New York: Basic Books.

Şendağ, S., & Odabaşı, F. (2009). Effects of an online problem based learning course on content knowledge acquisition and critical thinking skills. *Computers & Education, 53*, 132-141.

The Partnership for 21St Century Skills (2007) www.21stcenturyskills.org

Serrat O. (2017) Harnessing Creativity and Innovation in the Workplace. In: Knowledge Solutions. Springer, Singapore

Shen, Y., Ong, S. K. & Nee, A.Y.C. (2010). Augmented reality for collaboration product design and development. Design Studies, 31(2), 118-145.

Sousa, D. A. & Pilecki, T. (2013). From STEAM to STEAM: Using brain-compatible strategies to integrate the arts. Thousand Oaks, CA: Corwin.

Torrance, E. P. (1957). Psychology of survival. Unpublished manuscript, Air Force Personnel Research Center, Lackland Air Force Base, TX.

Torrance, E. P. (1962). Guiding creative talent. Englewood Cliffs, NY: Prentice-Hall.

Torrance, E. P. (1966). Torrance tests of creative thinking. Bensenville, IL: Scholastic Testing Company

Torrance, E. P. (1979). The search for satori and creativity. Buffalo, NY: Bearly Limited.

Torrance, E. P. (1988). The nature of creativity as manifest in its testing. In R. G. Sternberg (Ed.). The nature of creativity: Contemporary perspectives (p. 43-75). NY: Cambridge University Press.

Torrance, E. P. (1995). Why fly? A philosophy of creativity. Norwood, NJ: Ablex Publishing Corp.

Torrance, E. P. (2002). The manifesto: A guide to developing a creative career. Westport, CT: Ablex Publishing.

Turner, K. B. (2013). Northeast Tennessee Educator's Perception of STEM Education Implementation. Dissertation. East Tennessee State University.

Trilling, B. and Fadel, C. (2009) *21st Century Skills: Learning for Life in Our Times*, Wiley.

West, D., (Sept., 2013). Mobile learning: Transforming education, engaging students and improving outcomes. Center for Technology Innovation at Brookings. 1-16.

Yen, J. C. & Lee, C. Y. (2011). Exploring problem solving patterns and their impact on learning achievement in a blended learning environment. Computers & Education, 56, 138-145.

Yew, E. H. J & Goh, K. (2016). Problem-based learning: An overview of its process and impact on learning. ScienceDirect, 2, 75-79.

CHAPTER FIVE

COGNITIVE STYLE, CREATIVE ACHIEVEMENT, AND CREATIVE ENVIRONMENT

KUAN-CHEN TSAI

Abstract

The current exploratory study focuses from three aspects—person, product, and press—to examine creative process of Chinese undergraduates in Macau. More specifically, it attempts to understand to what extent these three factors interact with each other, as well as to examine the relationship among cognitive styles, creative achievements, and creative environments. The major finding of the current study is that the innovative cognitive style positively and significantly predicts students' creative achievement. However, the perception of being in a creative environment did not play a mediating role between cognitive style and creative achievement. Several limitations that might affect the interpretation of the findings were also discussed.

Keywords: Cognitive style, creative achievement, creative environment, Chinese students, Macau

Introduction

The concept of the "four Ps" (4Ps) – i.e., creative person, process, product, and press was initially proposed by Rhodes (1961) as a means to better understand the phenomenon of creativity, via identifying the salient characteristics of creative people; examining operational cognitive stages in the creative process; recognizing tangible creative products; and describing contextual factors affecting creativity. The 4Ps framework in fact stems from four distinct strands of creativity research, which Rhodes identified in the literature as valid methodological approaches and then operationalized.

Most of the early work on creativity sought to differentiate between (eminent) creative people and ordinary people, which reflects the traditional perspective of personality psychology (Barron & Harrington, 1981; Feist, 1998; MacKinnon, 1962). The cognitive approach then took the lead emphasizing "the internal dynamic of creativity" (Glăveanu, 2013, p. 141). In this process of creative action, creative thinking plays an important formative role (Amabile, 1990; Bear, 1993; Finke, Ward, & Smith, 1992); and – though the specifics of their proposed stages differ somewhat –a number of scholars have deployed similar models to explain the creative process (Allen & Thomas, 2011; Mumford & Gustafson, 1988; Runco, 2009; Simonton, 1983; Smith & Carlsson, 1990; Ward, Finke, & Smith, 1995; Weisberg, 1986). These models generally include two major components: divergent thinking and convergent thinking. In the phases associated with divergent thinking, the main task is to generate ideas (ideation), The phases involving convergent thinking, on the other hand, are devoted to evaluation and assessment of various creative ideas; this is crucial to the optimization of ideas that are practical and novel.

Several scholars of creativity employed a different approach: using regression models to investigate the quantity of creative products devised by eminent creative people, and to look for correlations between creative achievement, age, and different domains (e.g., architecture, novel-writing, or painting; Dennis, 1956; Lehman, 1960, 1966; Simonton, 1975, 1984, 2009). Their findings suggested that creativity is a more domain-general than a domain-specific phenomenon. Amid growing awareness of the complexity of creativity, several authors have recognized that environmental and cultural factors might also be important to consider when attempting to understand it. For instance, social psychologists who study creativity propose a holistic approach: systematically examining a range of contextual factors, and the interaction between the individual and his/her environment, so as to move the investigation beyond the inner mind of the creative person (Amabile, Hennessey, & Crossman, 1986; Csikszentmihalyi, 1990; Gruber, 1988; Harrington, 1990).

Several other researchers have investigated the relationship between cognitive style, creative achievement, and environment. Luh and Lu (2012) found that innovative cognitive style successfully predicted students' creative achievements, and that passion played a mediating role between innovative cognitive style and creative achievement. The results of several cross-cultural empirical studies generally support the idea that the socio-cultural environment has a significant impact on students' creative behaviors: with students from countries classified as "individualist" exhibiting better creative performance than those from "collectivist" countries (Dineen & Niu, 2008; Mouchiroud & Lubart, 2002; Ng & Smith, 2004; Niu & Sternberg, 2001; Niu, Zhang, & Yang, 2006; Rudowicz, Lok, & Kitto, 1995). Organizational- behavior scientists, meanwhile, have mainly been concerned with how working environments affect employees' creative performance, with the wider aim of improving that performance. They found that support from supervisors and co -workers, availability of resources, and policies conducive to creativity development could all encourage creative performance among employees (Amabile, Conti, Coon, Lazenby, & Herron, 1996; Hunter, Bedell, & Mumford, 2007; Oldham & Cummings, 1996; Unsworth, Wall, & Carter, 2005; Woodman, Sawyer, & Griffin, 1993).

While bearing in mind the importance of the creativity process within the 4Ps framework, the current exploratory study focuses mainly on the other three aspects: person, product, and press. More specifically, it attempts to understand to what extent these three factors interact with each other, as well as to examine the relationship among cognitive styles, creative achievements, and creative environments. It is hypothesized that people with more innovative cognitive styles will have more salient creative achievements. Additionally, it is hypothesized that individuals' perceptions of whether they are or are not in a creative environment play a mediating role in the relationship between their cognitive styles and their creative achievements.

Method

Participants

The sample for this study consisted of 243 Chinese students in Macau, chosen by convenience sampling. There were 160 females and 83 males in this sample, with an average age of 20.34 years.

Measures

Kirton Adaption-Innovation Inventory (KAI). The KAI was developed by Kirton (1976) to provide a deeper understanding of two cognitive types: adaptors, who prefer making incremental improvements within set boundaries, and innovators, who are willing to go beyond their comfort zones to achieve major change. The KAI contains 32-items with a 5-point Likert-scale ranging from 1 (*item does not describe me well*) to 5 (*item describes me well*). The possible scores therefore range from 32 to 160, and the higher a respondent's score, the more innovative an orientation that person can be said to have. For purposes of the current study, a score of 96 was treated as cut-off point: respondents who obtained scores of 97 and above (i.e., more than 3.0 per item on average) were coded as innovators, whereas people with scores of 96 and below (3.0 per item or less) were viewed as adaptors. The KAI also tests for three dimensions: Rule/Group Conformity (R), which indicates subjects' levels of adherence to group norms; Efficiency (E), which reflects their levels of concern for detail and reliability; and Sufficiency of Originality (SO), which refers to the likelihood that they will brainstorm creative ideas. The KAI is a popular measure in the organizational- research and creativity literature, and a number of studies have supported its reliability and validity (e.g., Bobic, Davis, & Cunningham, 1999; Houtz, Selby, Esquivel, Okoye, Peters, & Treffinger, 2003; Hsu, 2013; Keller & Holland, 1978; Kwang, Ang, Ooi, Shin, Oei, & Leng, 2005).

Biographical Inventory of Creative Behaviors (BICB). Creative achievement was measured using the BICB (Batey, 2007), a 34-item questionnaire that evaluates everyday creativity across different domains, including arts, crafts, creative writing, leadership, coaching, and mentorship. The BICB uses a forced-choice *yes/no* format, with *yes* scored as 1 and *no* as 0, yielding a range of possible scores from 0 to 34. Several studies suggest that the BICB has a solid factor structure and is a reliable self-report measure (Batey & Furnham, 2008; Silvia, Wigert, Reiter-Palmon, & Kaufman, 2012). A summary score aggregating the *yes* responses was obtained, with higher scores suggesting greater involvement in creative activities during the previous 12 months.

Creative Environment Perceptions (CEP). Mayfield and Mayfield (2010) have developed a parsimonious measure to evaluate employees' perceptions of whether their workplace is a creative environment. It contains nine items covering three dimensions: creativity support, work characteristics, and creativity blocks. Based on the results of structural equation model analysis, the authors found that the CEP attained valid measurement quality. The current study utilized an adapted version of the CEP, with six items rather than nine, each one slightly changed to reflect the non-workplace context. For example, the statement, "My supervisor encourages me to be creative" was changed to, "My teacher encourages me to be creative." A five-point Likert-type scale was used, ranging from 1 "strongly disagree" to 5 "strongly agree." A summary score aggregating the responses was obtained, with higher scores suggesting higher levels of perception that the environment was creative.

Process. All instruments were translated from English into Chinese by the researcher, checked by two experts, and then administrated in Chinese to all the respondents. The researcher obtained permission to collect data from the students, and then conducted three rounds of data-collection in a class setting. The process of completing the package took the respondents about 30 minutes, after which they were asked to provide their background information, including age, gender, and educational level.

Results

The means, standard deviations, and intercorrelations among six variables are reported in Table 1. Among six, three represent the respective summary scores for each of the three questionnaires used, and the other three – *originality*, *efficiency*, and *conformity* – were derived from the KAI. The majority of the respondents qualified as innovators, given the cut-off score of 96. The results of correlational analyses show that all correlation coefficients were positive and significant, with magnitudes ranging from weak (r = .16) to strong (r = .80).

Table 1

Means, Standard Deviations, and Intercorrelations of Scores for Six Measures

Measure	*M*	*SD*	1	2	3	4	5	6
1. BICB	12.71	4.72	--					
2. CEP	21.81	3.80	.23**	--				
3. KAI	111.94	11.23	.38**	.52**	--			
4. Originality	46.19	5.44	.38**	.53**	.76**	--		
5. Efficiency	23.78	3.98	.32**	.33**	.80**	.50**	--	
6. Conformity	41.98	5.39	.16**	.31**	.73**	.20**	.42**	--

** $p < .01$.

To identify whether gender differences and the two cognitive styles being studied had effects on creative achievement and perceptions regarding the creative environment, this study used a 2 (males or females) x 2 (adaptors or innovators) MANOVA with two dependent variables (BICB and CEP). Table 2 shows means and standard deviations for the dependent variables. In terms of both creative achievement and perceptions of the creative environment, innovators' mean scores were higher than those of adaptors across both genders.

Table 2

Mean Scores and Standard Deviations for Measures of BICB and CEP as Functions of Gender and Cognitive Style

	BICB	CEP		
Group	*M*	*SD*	*M*	*SD*
Males				
Adaptors	9	2.19	20.5	2.35
Innovators	12.86	5.28	22	4.04
Females				
Adaptors	8.25	2.75	18.5	1
Innovators	13.02	4.30	21.88	3.71

The results of multivariate and univariate ANOVAs are presented together in Table 3. Using Pillai's trace revealed significant effects of cognitive style on both creative achievement and perceptions of creative learning, $V = .54$, $F(2, 170)$, $p = .009$. In addition, separate univariate ANOVAs on the outcome variables suggested a significant effect of cognitive style on creative achievement, $F(1, 175) = 7.72$, $p = .006$, and a non-significant effect of cognitive style on perceptions of creative environment, $F(1, 175) = 3.76$, $p = .054$. Additionally, the results revealed that gender and interaction effects on interaction variables were not significant.

Table 3

Multivariate and Univariate Analyses of Variance for BICB and CEP

	Multivariate			Univariate					
				BICB			CEP		
Source	F^a	p	h^2	F^b	p	h^2	F^b	p	h^2
Gender	0.35	.703	.004	0.04	.849	.000	0.71	.401	.004
Style	4.80	.009	.054	7.72	.006	.043	3.76	.054	.022
Gender X Style	0.29	.751	.003	0.09	.770	.000	0.56	.456	.003

Note. Multivariate F ratios were generated from Pillai's statistic. [a]Multivariate df = 2, 170. [b]Univariate df = 1, 175.

Another aim of the current study was to examine the effects of students' characteristics on their creative achievement. As such, the criterion variable was creative achievement as measured by the BICB, and the four predictors were age, gender, cognitive style (KAI), and perceptions of creative environment (CEP). A hierarchical multiple regression analysis was conducted, with four independent variables entered into the regression equation in the model. The results of this are reported in Table 4, and indicate that only cognitive style as measured by KAI (b = .38, $p < .001$) was a valid predictor of students' creative achievement.

Table 4

Hierarchical Regression Analysis Summary for Four Variables Predicting Creative Achievement

Step and predictor variable	B	$SE B$	b	R^2	D R^2
Step 1:				.009	
Age	-.19	.15	-.10		
Step 2:				.010	.00
Gender	-.14	.76	-.02		
Step 3:				.148***	.14***
KAI	.16	.03	.38***		
Step 4:				.149***	.00
CEP	.03	.11	.03		

*** $p < .001$.

Discussion

According to zero-order correlations, the results of this study indicate that the relationships among cognitive styles, creative achievements, and creative-environments perceptions were positive and significant, with magnitudes ranging from weak (r = .23) to moderate (r = .52). In terms of the relationship between creative achievement and perceptions of a creative environment, it was found that among the students in our sample, innovators had higher scores than adaptors did. This suggests that, as compared to adaptors, innovators had greater daily creative achievement (as measured by BICB), as well as more awareness of their environment as creative (as measured by CEP). The results show that low correlations although statistically significant, which are educationally significant. As Weinbach (1989) reminded us, "statistically significant relationships may be trivial in the absolute sense is, on one level, a small but useful piece of information for the practitioner" (p. 37). The determination of whether or not statistically significant relationship is meaningful is based on data that is came from "insights into the current work environment and from common sense and practice logic" (Weinbach, 1989, p. 36). Our findings suggest that a possible link between creative environment and creative achievement, which implies that if educators want to facilitate creativity of their students, they should cultivate creative environment at the same time. After all, if students are involving in environment which is welcome creativity, the chance are that they could unleash their creative potential.

The results of MANOVA further support our first hypothesis that people with more innovative cognitive styles will have more salient creative achievements and this is in line with prior studies (e.g., Luh & Lu, 2012). Neither gender nor the interaction between gender and cognitive style had any effects on creative achievement. However, univariate ANOVAs indicated that the difference between adaptors and innovators with regard to perceptions of a creative environment were at the margin (p = .054). Our above mentioned finding that only cognitive style was a valid predictor of the respondents' creative achievement further confirms our first hypothesis; however, it does not support our second hypothesis, that the perception of a creative environment plays a mediating role in the relationship between cognitive style and creative achievement.

This study has several limitations that might affect the interpretation of the findings. First, our sample pool was entirely recruited from Chinese undergraduates in art and design programs, and therefore might not be very representative of other groups – especially insofar as the majority of our respondents were classified as innovators. On the one hand, this trends to validate the KAI scale; but on the other, it might be seen as contaminating our results. Secondly, this study was cross-sectional and relied on self-report instruments. Although this combination of methods has been validated by other studies (Silvia et al., 2012), the use of a longitudinal or experimental design might be more appropriate for future study of students' creative achievement, as it would allow the subjects to create work that is then evaluated by experts. Through using longitudinal or experimental approach, we could understand the long term effects of students' creative characteristics, sustainability of their creative outputs, and effect of different environments. In light of these limitations, the present study probably underestimates the real effect sizes. Another line of questioning for future researchers might be that, if cognitive styles have a psychological basis, then what type of environments facilitate the conservative disposition of the adaptor, i.e., increases individuals' acceptance of the status quo?

Conclusion

The major finding of the current study is that the innovative cognitive style positively and significantly predicts students' creative achievement. However, the perception of being in a creative environment did not play a mediating role between cognitive style and creative achievement. Theoretically, it has been suggested that the intersection and interaction of environment with other variables cannot be separated when examining the possible factors influencing individuals' creativity (Csikszentmihalyi, 1990; Mayfield & Mayfield, 2010). Therefore, there is still scope for further investigation.

References

Allen, A. P., & Thomas, K. E. (2011). A dual process account of creative thinking. *Creativity Research Journal*, *23*(2), 109-118.

Amabile, T. M. (1990). Within you, without you: The social psychology of creativity, and beyond. In M. A. Runco & R. S. Albert (Eds.), *Theories of creativity* (pp. 61–91). Newbury Park, CA: SAGE.

Amabile, T. M., Conti, R., Coon, H., Lazenby, J., & Herron, M. (1996). Assessing the work environment for creativity. *Academy of Management Journal*, *39*(5), 1154-1184.

Amabile, T. M., Hennessey, B.A., & Crossman, B. S. (1986). Social influences on creativity: The effects of contracted-for rewards. *Journal of Personality and Social Psychology*, *50*(1), 14-23.

Bear, J. (1993). *Creativity and divergent thinking: A task-specific approach*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Batey, M. (2007). *A psychometric investigation of everyday creativity*. Unpublished doctoral dissertation. University College, London.

Batey, M., & Furnham, A. (2008). The relationship between measures of creativity and schizotype. *Personality and Individual Differences*, *45*(1), 816-821.

Barron, F., & Harrington, D. M. (1981). Creativity, intelligence, and personality. *Annual Review of Psychology*, *32*(1), 439-476.

Bobic, M., Davis, E., & Cunningham, R. (1999). The Kirton Adaptation-Innovation inventory: Validity issues, practical questions. *Review of Public Personnel Administration*, *19*(2), 18-31.

Csikszentmihalyi, M. (1990). The domain of creativity. In M. A. Runco & R. S. Albert (Eds.), *Theories of creativity* (pp. 190–212). Newbury Park, CA: SAGE.

Dennis, W. (1956). Age and achievement: A critique. *Journal of Gerontology*, *11*(3), 331-333.

Dineen, R., & Niu, W. (2008). The effectiveness of western creative teaching methods in China: An action research project. *Psychology of Aesthetics, Creativity, and the Arts, 2*(1), 42-52.

Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Personality and Social Psychology Review*, *2*(4), 290-309.

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications*. Cambridge, MA: The MIT Press.

Glăveanu, V. P. (2013). Creativity and folk art: A study of creative action in traditional craft. *Psychology of Aesthetics, Creativity, and Arts*, *7*(2), 140-154.

Gruber, H. E. (1988). The evolving systems approach to creative work. *Creativity Research Journal*, *1*(1), 27-51.

Harrington, D. M. (1990). The ecology of human creativity: A psychological perspective. In M. A. Runco & R. S. Albert (Eds.), *Theories of creativity* (pp. 143–169). Newbury Park, CA: SAGE.

Houtz, J. C., Selby, E., Esquivel, G. B., Okoye, R. A., Peters, K. M., & Treffinger, D. J. (2003). Creativity styles and personal type. *Creativity Research Journal*, *15*(4), 321-330.

Hsu, H.-J. (2013). Factors affecting employee creativity in Taiwan's Hakka clothing industry. *Social Behavior and Personality: An International Journal*, *41*(2), 271-282.

Hunter, S. T., Bedell, K. E., & Mumford, M. D. (2007). Climate for creativity: A quantitative review. *Creativity Research Journal*, *19*(1), 69-90.

Keller, R. T., & Holland, W. E. (1978). A cross-validation study of the Kirton Adaption-Innovation inventory in three research and development organizations. *Applied Psychological Measurement*, *2*(4), 563-570.

Kirton, M. J. (1976). Adaptors and innovators: A description and measure. *Journal of Applied Psychology*, *61*(1), 622-629.

Kwang, N. A., Ang, R. P., Ooi, L. B., Shin, W. S., Oei, T. P. S., & Leng, V. (2005). Do adaptors and innovators subscribe to opposing values? *Creativity Research Journal*, *17* (2&3), 273-281.

Lehman, H. C. (1960). The age decrement in outstanding scientific creativity. *The American Psychologist*, *15*(2), 128-134.

Lehman, H. C. (1966). The most creative years of engineers and other technologists. *Journal of Genetic Psychology*, *108*(2), 263-277.

Luh, D.-B., & Lu, C.-C. (2012). From cognitive style to creativity achievement: The mediating role of passion. *Psychology of Aesthetics, Creativity, and the Arts*, *6*(3), 282-288.

MacKinnon, D. W. (1962). The nature and nurture of creative talent. *American Psychologist*, *17*(7), 484-495.

Mayfield, M., & Mayfield, J. (2010). Developing a scale to measure the creative environment perceptions: A questionnaire for investigating garden variety creativity. *Creativity Research Journal*, *22*(2), 162-169.

Mouchiroud, C., & Lubart, T. (2002). Social creativity: A cross-sectional study of 6- to 11-year-old children. *International Journal of Behavioral Development*, *26*(1), 60-69.

Mumford, M. D., & Gustafson, S. B. (1988). Creativity syndrome: Integration, application, and innovation. *Psychological Bulletin*, *103*(1), 27-43.

Ng A., K., & Smith, I. (2004). The paradox of promoting creativity in the Asian classroom: An empirical investigation. *Genetic, Social & General Psychology Monographs*, *130*(4), 307-330.

Niu, W., & Sternberg, R. J. (2001). Cultural influences on artistic creativity and its evaluation. *International Journal of Psychology*, *36*(4), 225-241.

Niu, W., Zhang, J. X., & Yang, Y. (2006). Does culture always matter: For creativity, yes, for deductive reasoning, no! In J. C. Kaufman & J. Baer (Eds.), *Creativity and reason in cognitive development* (pp. 282-296). New York, NY: Cambridge University Press.

Oldham, G. R., & Cummings, A. (1996). Employee creativity: Personal and contextual factors at work. *Academy of Management Journal*, *39*(3), 607 -634.

Rhodes, M. (1961). An analysis of creativity. *Phi Delta Kappan*, *42*(7), 305-310.

Rudowicz, E., Lok, D., & Kitto, J. (1995). Use of the Torrance Tests of Creative Thinking in an exploratory study of creativity in Hong Kong primary school children: A cross-cultural comparison. *International Journal of Psychology*, *30*(4), 417-430.

Runco, M. A. (2009). Simplifying theories of creativity and revisiting the criterion problem a comment on Simonton's (2009) hierarchical model of domain-specific disposition, development, and achievement. *Perspectives on Psychological Science*, *4*(5), 462-465.

Silvia, P. J., Wigert, B., Reiter-Palmon, R., & Kaufman, J. C. (2012). Assessing creativity with self-report scales: A review and empirical evaluation. *Psychology of Aesthetics, Creativity, and the Arts*, *6*(1), 19-34.

Simonton, D. K. (1975). Age and literary creativity: A cross-cultural and transhistorical survey. *Journal of Cross-Cultural Psychology*, *6*(3), 259-278.

Simonton, D. K. (1983). Creativity productivity and age: A mathematical model based on a two-step cognitive process. *Developmental Review*, *3* (1), 97-111.

Simonton, D. K. (1984). Artistic creativity and interpersonal relationships across and within generations. *Journal of Personality and Social Psychology*, *46*(6), 1273-1286.

Simonton, D. K. (2009). Varieties of (scientific) creativity a hierarchical model of domain-specific disposition, development, and achievement. *Perspectives on Psychological Science*, *4*(5), 441-452.

Smith, G. J. W., & Carlsson, I. M. (1990). *The creative process: A functional model based on empirical studies from early childhood to middle age*. Madison, CT: International Universities Press.

Unsworth, K. L., Wall, T. D., & Carter, A. (2005). Creative requirement: A neglected construct in the study of employee creativity? *Group & Organization Management*, *30*(5), 541-560.

Ward, T. B., Finke, R. A., & Smith, S. M. (1995). *Creativity and the mind: Discovering the genius within*. New York, NY: Plenum Press.

Weinbach, R. W. (1989). When is statistical significance meaningful? a practical perspective. *The Journal of Sociology & Social Welfare*, *16*(1), article 4. Retrieved from http://scholarworks.wmich.edu/jssw/vol16/iss1/4

Weisberg, R. (1986). *Creativity: Genius and other myths*. New York, NY: W. H. Freeman and Company.

Woodman, R. W., Sawyer, J. E., & Griffin, R. W. (1993). Toward a theory of organizational creativity. *Academy of Management Journal*, *18*(2), 293-321.

CHAPTER SIX

MAKING THE OLD NEW AGAIN: INFUSING STEM EDUCATION WITH DELIBERATE CREATIVITY

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Abstract

Since its founding over 100 years ago, 4-H has committed itself to developing community leaders invested in innovation. At the end of the 19th century, universities seeking to share agricultural advances found that while adults were more committed to traditional ways, young people were more open-minded and willing to explore new ideas. Community clubs focused on applied experiential learning were formed to tackle the challenges faced by the nation's regional industries.

The National Education Association, a founding member of the Partnership for 21st Century Skills, has laid out a framework of skills that it argues are essential for all who seek to be productive citizens of this century. This framework provides a useful outline to examine skill-development outcomes innovative 4-H educators seek to achieve: creativity and innovation, critical thinking and problem-solving, communication, and collaboration.

Today, 4-H's community and in-school enrichment projects provide a robust variety of STEM programming striving to improve our national capacity in critical scientific areas and fuel communities ready to embrace the primary challenges of this century. Through deliberate community development that norms STEM education, scientific exploration, and creative problem-solving as necessary life skills, the young people served are empowered to make a difference throughout their lives.

Historical Underpinnings of 4-H

Since its founding over 100 years ago, 4-H has committed itself to developing community leaders invested in innovation. With strong roots that are deeply connected to American culture (Van Horn, Flanagan, & Thomson, 1999), 4-H has long been acknowledged as a premier positive youth development organization (Anderson, Bruce, & Mouton, 2010). Its programs aim to help young people become strong and impactful citizens (Stedman, 2004) with a robust understanding of how to identify and solve the challenges they encounter.

An arm of the Cooperative Extension System of the United States Department of Agriculture, the founding of 4-H came about in the era of scientific management in which carefully tested techniques were thought to be the key to optimizing efficiency and economic growth. The aim of this effort in rural America was to industrialize farming by getting farmers to adopt the methods and techniques being developed in the states' land grant universities. The initiative was not only aimed at decreasing food costs but also to address other public concerns such as preventing soil exhaustion and fostering improved sanitation practices (Peters, 2002).

The extension agents' role in this work was to encourage behavioral changes and the adoption of agricultural innovations. The first decades of the extension system were dedicated to accomplishing a number of ambitious goals:

> Improving crops and animals,
> Developing cooperative marketing,
> Fighting diseases and pests
> Beautifying homes and communities,
> Setting up 4-H clubs,
> Advancing public health and nutrition,
> Establishing community gardens,
> Developing community arts and recreation programs and events, and
> Responding to the emergency relief needs of both war and depression. (Peters, 2002)

During this time, county extension agents spent much of their time organizing relationships between farm families, small-town merchants and bankers, and government experts. This was wise as the strongest extension programs are those that result from a balance of ownership between extension professionals and key volunteers (King & Safrit, 1998).

However, farmers are not likely to change their practices from a simple distribution of pamphlets or by having demonstration plots available at government-owned farms. Seaman Knapp, often referred to as the "Father of Extension," realized that a much more effective tactic would be for the farmers' children to demonstrate the new practices right on their own farms (Enfield, 2001a). Fortunately, at this same time, rural families were expressing concern that their children's education was not practical enough, that they were not learning to understand and appreciate nature or agricultural techniques (Enfield, 2001b). In fact, a well-respected education expert of the time declared that rural schools were making children "unfit" to live in agricultural environments (Enfield, 2001a).

This disconnect led to the creation of the antecedents of the 4-H program in numerous locations throughout the United States (Enfield, 2001b). Extension educators recruited youth to act as intermediaries between the communities' farmers and university researchers (Van Horn, Flanagan, & Thomson, 1998), and it worked. Children were now thriving in educational environments in which they were actively engaged and that led to meaningful applications of their learning. Parents were exposed to new agricultural research and were convinced to adopt new farming practices (Van Horn et al., 1998).

Building on this success, demonstration clubs utilizing meaningful, real-life learning sprang up across the United States. By the 1930s, this movement included over 800,000 young people with a growth rate of roughly 10 percent each year (Enfield, 2001a). The attraction of this programming was not only that youth were eager to try out new ideas but were drawn to the clubs' four essential elements: belonging, independence, mastery, and generosity. Of particular interest to our discussion is the concept of mastery which not only speaks to skill and knowledge development but also to the self-efficacy necessary for taking risks and accepting challenges (Anderson, Bruce, & Mouton, 2010).

Understanding the historical mission of 4-H and the elements of its programming that impact youth, families, and communities make it easier to understand how 4-H continues to develop engaged citizens through science-based education (Russell, 2001). Experiences only result in learning if the youth understands what happens during the experience, sees patterns emerge, and can apply this understanding in other situations (Enfield, 2001b). Thus, the learner must have the opportunity to apply the knowledge acquired practically. Experiential learning as originally depicted by Dewey and further elaborated on by Lewin is seen "as a cycle of concrete experience, observation and reflection, formation of abstract concepts and testing the implications of these concepts in new situations" (Rehm, 2014). Definitions of youth development depict a process by which the young people acquire the skills the meet challenges in a wide array of areas—cognitive, social, and civic among them (Edelman, Gill, Comerford, Larson, & Hare, 2004).

Constructivist learning theory asserts that through experience with social and physical environments learners construct mental models that allow them to organize their thoughts. Over time knowledge increases, is modified, and matures as new information and experiences must be accommodated (Smith, 2008). However, science is typically taught through lessons that involve the memorization of facts. When 4-H programming puts science education in a context in which learners are encouraged to challenge their thinking and formulate new ways of looking at scientific phenomena through the lenses of their environmental realities, it is tapping into critical factors that affect both learning and future knowledge transfer (Smith, 2008).

It is important that we enable our youth to be scientifically literate citizens who are curious about their planet, question things and find solutions, and make good decisions about the issues they face. Moreover, creativity is essential when developing scientific learning (Park & Seung, 2008). Sadly, if creative expression is not deliberately encouraged, it is unlikely learners will be enabled to achieve their full creative potential. This aspect of 4-H programming is key as its core intention is to develop creative leaders who can tackle the challenges faced by regional industries.

This leadership aspect has been central to 4-H programming from the start. Its clubs had leadership advisors from the time of the Morrill Act of 1862 (Fritz et al., 2003). As the organization matured, teen leaders were supported by additional programming at the state, regional, and national levels. At the national level, presidential recognitions were given to each boy and girl in the areas of leadership, citizenship, and achievement (Hoover, Scholl, Dunigan, & Mamontova, 2007).

Numerous studies evaluating the impact of 4-H have concluded that its members develop abilities in social skills, personal development, leadership, and responsibility (Anderson, Bruce, & Mouton, 2010; Bruce, Boyd, & Dooley, 2005), and agricultural education plays a key role in leadership education in many land-grant universities (Simonsen et al., 2014). Thus, 4-H programming strives to empower youth with the core values of philanthropy and civic engagement, and it is very successful (Stedman, 2004).

In particular, two types of leaders are developed to address the community's challenges. First are the catalytic leaders who inspire others to "think, plan, dream, focus and develop vision." Due to this leader's guidance, people may reconsider previously held thinking and become engaged with new ideals of strategy, tactics, and paradigms (Culp & Cox, 2002). Second are the innovative leaders who share novel procedures, inventions, and alternatives. These leaders will not only be able to think creatively but will be able to sell the benefits of this new way of thinking to others (Culp & Cox, 2002). These leaders are well positioned to search for more efficient ways of doing things and developing new procedures to meet an unmet need.

Current Societal Demands and the Pedagogical Vision to Address Them

Understanding the nature of science, technology information, and mathematical calculations can influence how leaders young and old think about the world and make decisions. Researchers Tate, Jones, Thorne-Wallington, and Hogrebe (2012) argue that all citizens need STEM understanding to make sound decisions for themselves, their families, and their communities. They argue that STEM learning experiences encourage experimenting, questioning, drawing reasonable conclusions, and communicating creative solutions.

These skills are crucial for today's students who face social, economic, cultural, and political issues where disciplinary knowledge stands equal with creativity, communication, critical thinking, and collaboration (National Education Association, 2012). There is a growing recognition that science, technology, engineering, and mathematics (STEM) educational experiences, particularly when designed to foster creativity, collaboration, and persistence, lead to better problem-solving skills (Hadani & Rood, 2018). Students are preparing for modern challenges such as discovering new medical advances, ways to address climate change, alternatives to sustain our environment, and technological innovations. These problem-solving challenges all require STEM-based solutions (National Academy of Engineering, 2016).

While problem-solving skills have historically been taught in the formal traditions of past generations, today, informal learning spaces (afterschool and summer programs, museums, science centers, libraries, etc.) complement and deepen children's school-based STEM education. This extra exposure is particularly important when you consider the number of hours that children spend in these environments. Falk and Dierking (2010) discuss how average Americans spend less than five percent of their lives in classrooms and contend that the best route to scientific literacy is through free-choice learning experiences across all ages, such as what is offered in community-based programs and the vast array of digital media now available.

21st-century students need STEM skills at a level unheard of in prior generations. Offering both formal and informal learning opportunities through an integration of community and school environments intentionally blurs the boundaries of where and by whom children are taught STEM concepts. This comprehensive "learning ecosystem" approach represents a significant and creative shift in how we think about educating our children, providing the holistic STEM education our youth need for their futures (Krishnamurthi, Noam, & Ballard, 2014). By shifting where education occurs, schools can share both responsibility and opportunities across a range of organizations, players, and programs. This cross-setting learning is of great importance, especially for underprivileged populations who may not have equal access to extra-curricular activities (Bransford et al., 2006; Covay & Carbonaro, 2011; Feldman & Matjasko, 2005).

To accomplish this type of learning ecosystem for 21st-century students, the National Education Association (2012), a founding member of the Partnership for 21st Century Skills (2011), developed a framework called "the 4 Cs." The Cs are creativity and innovation, critical thinking and problem solving, communication, and collaboration (National Education Association, 2012). These skills are the springboards from which STEM education can be introduced, nurtured, and practiced.

The Four Cs

The 4 Cs model has become a common language among American educators and is often embedded in subject areas throughout a school curriculum (Rehm, 2014). According to 2010 American Management Association (AMA) research, 80 percent of the executives surveyed believed infusing the 4 Cs into subject areas would ensure that students were better prepared to enter the workforce, lauding the importance of thinking critically, solving problems, collaboration, and communication.

It is important to acknowledge that in practice the skills do not operate in isolation but are interdependent and overlapping. For example, creativity and innovation have a social component requiring interpersonal skills to communicate and collaborate effectively. Let us look into this a bit further using STEM-oriented descriptions based on literature from the Partnership for 21st Century Skills (2011) and the New York Global STEM Alliance (2018):

- **Creativity:** Students have multiple opportunities to approach problems from many different perspectives, including their own. Novel and creative approaches or solutions are explicitly valued, allowing students to devise their own paths. Teacher and student supports are included to facilitate synthesis of activity outcomes and reflection upon the value of innovative approaches and solutions.

- **Critical Thinking:** Students have opportunities to evaluate multiple sources of information, evidence, and primary material; to select appropriate material to support arguments; to critique the work of others; and to differentiate evidence from inference and opinion. In problem solving, students have opportunities to develop their ability to generate solutions to a range of STEM-based problems and scenarios, including organizing ideas, defining goals and milestones, and executing plans.
- **Communication:** Students have frequent and varied opportunities to practice and demonstrate their ability to communicate clearly, accurately, and persuasively about STEM topics to multiple audiences, both formal and informal.
- **Collaboration:** Students have frequent opportunities to engage in group work. Teacher and student supports are included to help students work together to plan, organize, and execute activities. Activities are structured to support co-construction of knowledge and work products (e.g., students are assigned roles within groups so that each student can contribute). To the extent possible, STEM content is presented in an integrated, multidisciplinary approach in which students have multiple opportunities to apply STEM skills and knowledge in the context of STEM activities, problems, and practices. (New York Global STEM Alliance, 2018, pp. 4-8)

The ability to think critically, be creative, collaborate with peers, and communicate effectively is fundamental to youth's engagement in our global society. However, the 4 Cs are just one component of a pedagogical vision for the interdisciplinary nature of STEM. We advocate for an integrated pedagogical system positioned in the shared learning ecosystem of a community. This vision specifically connects the learning theories of experiential learning (Kolb, 1984) and constructivism (Dewey, 1933; Smith, 2008) with the established conceptual frameworks of the 4 Cs model (2011) and the positive youth development models (Lerner et al., 2005) utilized in the 4-H framework of youth leadership development (Anderson et al., 2010; Ferber, Pittman, & Marshall, 2002). Figure 1 illustrates this conceptual vision for integrated STEM education.

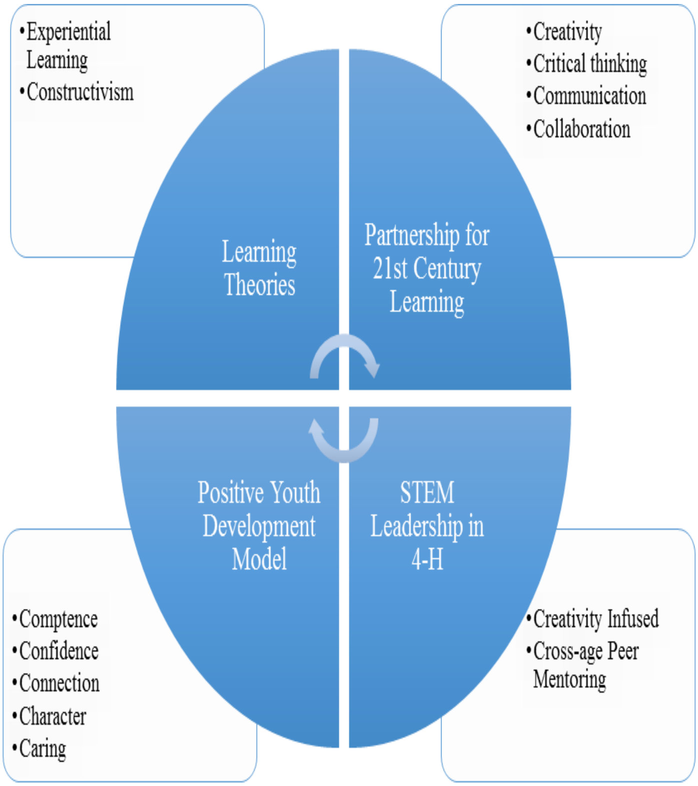

Figure 1: Conceptual vision framework for Creative STEM Learning

While teachers acknowledge that STEM education helps promote the 21st-century skills, for many it is not an easy task to integrate subjects, theories, and conceptual frameworks (El-Deghaidy, Mansour, Alzaghibi, & Alhammad, 2017). Connecting ideas across STEM disciplines is difficult work, and educators do not always have the knowledge, training, materials, or administrative support to make this happen (McGinnis, 2017). Kelly and Knowles (2016) address the complexity of STEM integration, stating that making crosscutting STEM connections requires teachers teach STEM content in specific intentional, deliberate ways (Kelley & Knowles, 2016).

As an alternative, schools have been successfully providing integrative approaches by partnering with university and community colleagues (Stohlmann, Moore, & Roehrig, 2012). Establishing partnerships with 4-H and Extension educators enhances both teachers' and students' experiences by extending both professional development opportunities and community engagement. 4-H is well positioned within community learning ecosystems to make our pedagogical vision a reality. To illustrate this, we provide a case study of an existing 4-H program that is using deliberate creativity in STEM education with the goal of empowering the leaders of tomorrow.

4-H Today: Use of Deliberate Creativity in STEM Education to Empower Youth

As stated previously, the 4-H program of today began as a way to address the challenges of disseminating agricultural innovation in rural communities and empowering their youth to become creative leaders. 4-H is now the largest youth development program in the United States and is based out of the Cooperative Extension arms of over 100 public universities (4-H, 2018). Today, close to six million 4-H members are involved in traditional community based out-of-school clubs and in school/after-school based programming in both urban and rural regions. The State of Maine's 4-H Community Central program engages elementary school-age youth in two of Maine's largest cities: Portland and Lewiston. Community Central seeks to engage youth in STEM programming and build stronger families through 4-H programming at public housing sites, in schools, and through a network of community partners.

Creative Problem Solving in the 4-H Model

Creative problem solving in 4-H is based on the principle of "learning by doing" from Kolb's Experiential Learning Model (1984). Norman and Jordan (2006) outline the five specific steps to this model:

1. Participant(s) *experience* the activity by performing or doing it.
2. Participant(s) *share* the experience by describing what happened.
3. Participant(s) *process* the experience to determine what was most important and identify common themes.
4. Participant(s) *generalize* from the experience and relate it to their daily lives.
5. Participant(s) *apply* what they learned to a new situation.

Often missing from science classrooms is the openness that allows for creativity and the imagination that allows students to explain what they encounter (Fahem, Hacieminoglu, Ali, & Yager, 2016). "Learning by doing" provides 4-H youth with a structured atmosphere for exercising creativity while exploring scientific concepts. Fahem et al.'s (2016) study utilized six features that relate creativity to school science: divergent thinking, open-ended questioning, generation of unusual ideas, generation of metaphors, solving problems and puzzles, and designing devises and machines (p. 73).

These features all play a part in both the 4-H Experiential Learning Model and the process for Creative Problem Solving.

STEM education through the 4-H Experiential Learning Model clearly supports the process of Creative Problem Solving (CPS). As an illustration of this match, see a basic description of the Creative Education Foundation's CPS Learner's Model (2018) below:

1. Clarify – Explore the Vision, Gather Data, Formulate Challenges
2. Ideate – Explore Ideas
3. Develop – Formulate Solutions
4. Implement – Formulate a Plan

Of course, creativity within STEM classrooms/activities needs to be encouraged and strengthened by educators. Students have to feel comfortable in their classrooms to feel that they can openly share their ideas and that their efforts are appreciated (Byrum, 2015). Simply put, deliberate encouragement of creativity will empower youth interested in STEM careers to be innovative thinkers that create impact. For example, the field of engineering stresses the necessity of creative efforts so that it can continue to design innovative products for consumers (Charyton, 2015), but only 3% of the population associates "creative" with engineering (Stouffer, Russell, & Oliva, 2004). 4-H programming has the opportunity to change this perception and infuse creativity into STEM programming that reaches millions of members across the United States.

The deliberate inclusion of creativity in STEM has led to the use of the acronym STEAM: Science, Technology Engineering, Arts, and Mathematics. This explicit addition of arts "advocates for creativity and expression to be included as a core part of any interdisciplinary approach" (Harris & de Bruin, 2017b). When youth participants in STEM programming are encouraged to be creative, to be unafraid of failure, and to embrace trial and error, they "become more active participants in their own investigations and more involved in their own learning" (Fahem et al., 2016). This call for creativity is echoed by Schmidt (2010) who argues that creativity should be an essential element of science education programs.

Park and Seung (2008) advocate for training in deliberate creativity methods such as CPS. They state that "Creative Problem Solving aims to give students an opportunity to work with open-ended problems or tasks that require creative solutions. With this strategy, students become self-directed learners, who are aware of their ownership of learning, which helps to advance students' scientific literacy" (p. 48). To achieve this impact for its participants, Community Central provides deliberate creativity training to its Teen Leaders, positively impacting their ability to mentor youth participants, help youth reflect upon their learning, and design program curriculum.

Creativity-Infused Leadership Development for Teen Leaders

"As with leadership, it is a far too common a notion that creativity is an inherent gift that one either does or does not have. Not only can creativity be taught, it is taught effectively at all levels of education, from kindergarten to graduate school" (Stouffer et al., 2004). Community Central deliberately infuses creativity into program development and design, particularly with its teen leader model. At afterschool and summer sites, high school students assist with program delivery to elementary students primarily in grades three to six. When teaching 4-H STEM curriculum, Community Central staff members utilize a Train-the-Trainer model to educate high school students. The Train-the-Trainer model pairs teen leaders with 4-H staff and volunteers who provide the curriculum, materials, and support necessary for STEM activities. The teens then present the activity leading staff through the project and post-activity reflection. This Train-the-Trainer model allows teen leaders/teachers to experience the activity and participate in reflection techniques before they facilitate youth completing the project.

Empowering Youth in Creative STEM

The use of teen-age teachers benefits both the elementary and high school students. Young students respond well to having a teacher and positive role model who is closer to their age group (Lee & Murdock, 2001). The teens are given the opportunity to develop their creative problem solving and leadership skills. After sessions, 4-H Community Central staff assess the session with teen leaders and debrief any challenging situations, review what skills can be further enhanced, and encourage use of the creative problem solving process for continuous improvement. "When adequately prepared and supported, teenaged teachers can make tremendous personal gains" (Lee & Murdock, 2001) and are in a position to model their skills for young STEM program youth. If teachers model creative thinking and creative problem solving, youth are more comfortable with taking creative risks (Harris & de Bruin, 2017a). Thus, Community Central provides two layers of mentoring relationships.

Teens are mentored by 4-H staff on a variety of topics, including asking purposeful questions, keeping youth on task, and empowering youth when they are frustrated or afraid of failure. Armed with these skills, Teen Leaders are often asked to lead youth in small groups. "Allowing students the opportunity to justify answers through reflection and self-assessment [is] key to activating kids' agency/control of their own learning and hence their creativity" (Harris & de Bruin, 2017a). This technique allows teens to form stronger mentoring relationships with youth participants and further enhance youth creativity during programming. "Collaboration is a dominant contributor to creative acts and thinking, and nourishes both individual and collective attributions toward creativity" (Harris & de Bruin, 2017b). One of the 4-H

Essential Elements of Positive Youth Development, “Engagement in Learning,” underlines the need for learners having a high “degree of self-motivation and an inexhaustible capacity for creativity” (4-H, 2016). This capacity for creativity is deliberately enhanced through the use of the cross-age peer mentoring model.

Cross-age Peer Mentoring Model

The 4-H principle of “Learning by Doing” is utilized twofold in the leadership development aspect of the Community Central program. First, Teen Leaders are mentored by 4-H staff in a variety of leadership concepts. Second, teen leaders apply the concepts learned to their work with 4-H youth. Karcher (2008) argues that this cross-age peer mentoring model produces Teen Leaders with enhanced leadership abilities, collaboration skills, academic achievement, and self-esteem.

In fact, 4-H program outcomes explicitly name the development of 21st Century Life Skills. This model states that participants will “develop the skills, attitudes, and abilities that will lead to the development of the 5 Cs of Positive Youth Development: Competence, Confidence, Connection, Character, and Caring” and that youth and teens will “contribute to the health, growth, and well-being of self, family, community, nation, and the world” (4-H, 2012). The cross-age peer mentoring model provides opportunity to support this outcome in both elementary school children and high school aged youth simultaneously.

As teen leaders engage with elementary age children, they lead children to a desire to learn science and inspire creativity within science. This need is just as true today as it was when 4-H was created. A recent study conducted by Taylor, Jones, Broadwell, and Oppewal (2008) found that 76% of teachers and scientists agreed that creative thinking skills and a desire to learn science are just as important, if not more important, than critical thinking skills.

Conclusion

The mission of 4-H today remains in balance with its historical purpose. Its community and in-school enrichment projects provide robust STEM programming that strives to improve our national capacity in critical scientific areas and fuel communities ready to embrace the primary challenges of this century. Through deliberate community development that norms STEM education, scientific exploration, and creative problem-solving as necessary life skills, the young people served are empowered to make a difference throughout their lives.

References

4-H. (2012). *National 4-H logic model*. Retrieved from https://4-h.org/wp-content/uploads/2016/02/National-4-H-Logic-Model.pdf

4-H. (2016). *Essential elements of 4-H youth development: Key ingredients for program success.* Retrieved from https://4-h.org/wp-content/uploads/2016/02/full-training-curriculum-and-appendices.pdf

4-H. (2018). *Benefits of 4-H.* Retrieved from https://4-h.org/parents/benefits

American Management Association. (2010). *Critical Skills Survey: Executive summary*. Retrieved from https://www.amanet.org/news/ama-2010-critical-skills-survey.aspx

Anderson, J., Bruce, J., & Mouton, L. (2010). 4-H made me a leader: A college-level alumni perspective of leadership life skill development. *Journal of Leadership Education, 9*(20), 35-49.

Bransford, J., Stevens, R., Schwartz, D., Meltzoff, A., Pea, R., Roschelle, J., Vye, N., Kuhl, P., Bell, P., Barron, B., Reeves, B., & Sabelli, N. (2006). *Learning theories and education: Toward a decade of synergy*. In: P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology* (pp. 209–244). Mahwah, NJ: Lawrence Erlbaum Associates.

Bruce, J. A., Boyd, B. L., & Dooley, K. E. (2005). 4-H leadership training and transfer of leadership skills. *Journal of Leadership Education, 4* (1), 50-60.

Byrum, D. (2015). Encouraging creativity in a STEM classroom. *K-12 STEM Education, 1*(1), 13-21.

Charyton, C. (2015). Creative engineering design: The meaning of creativity and innovation in engineering. In C. Charyton (Ed.), *Creativity and innovation among science and art* (135-152). London: Springer.

Covay, E., & Carbonaro, W. (2010). After the bell: Participation in extracurricular activities, classroom behavior, and academic achievement. *Sociology of Education, 83*(1), 20–45. doi: 10.1177/0038040709356565

Creative Education Foundation. (2018). *The CPS process*. Retrieved from http://www.creativeeducationfoundation.org/creative-problem-solving/the-cps/process

Culp, K., & Cox, K. (2002). Developing leadership through adult and adolescent partnerships in the third millennium. *Journal of Leadership Education, 1*(1), 41-57.

Dewey, J. (1933). *How we think: A restatement of the relation of reflective thinking to the educative process*. Boston: D. C. Heath.

Edelman, A., Gill, P., Comerford, K., Larson, M., & Hare, R. (2004). *Youth development and youth leadership*. Washington, DC: National Collaborative on Workforce and Disability for Youth.

El-Deghaidy, H., Mansour, N., Alzaghibi, M., & Alhammad, K. (2017). Context of STEM integration in schools: Views from in-service science teachers. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(6), 2459-2484.

Enfield, R. P. (2001a). Connections between 4-H and John Dewey's philosophy of education. *Focus* [monograph series]. Davis, CA: 4-H Center for Youth Development, University of California, Davis. Retrieved from http://www.ucanr.org/sites/UC4-H/files/1234.pdf

Enfield, R. P. (2001b, April). *Head, heart, hands and health: "Experience and education"by Dewey's criteria?* Paper presented at the Annual Meeting of the American Educational Research Association, Seattle, WA.

Fahem, S. M., Hacieminoglu, E., Ali, M. M., & Yager, R. E. (2016). Features of creativity that improve student science learning. *K-12 STEM Education, 2*(3), 73-81.

Falk, J. H., & Dierking, L. D. (2010). The 95 percent solution school is not where most Americans learn most of their science. *American Scientist*, *98*(6), 486-493.

Feldman, A. F., & Matjasko, J. L. (2005). The role of school-based extracurricular activities in adolescent development: A comprehensive review and future directions." *Review of Educational Research, 75*(2), 159-210.

Ferber, T., Pittman, K., & Marshall, T. (2002). *State youth policy: Helping all youth to grow up fully prepared and fully engaged*. Washington, DC: The Forum for Youth Investment. Retrieved from http://forumfyi.org/content/state-youth-policy-hel

Fritz, S., Townsend, C., Hoover, T., Weeks, W., Carter, R., & Nietfeldt, A. (2003). An analysis of leadership offerings in collegiate agricultural education departments. *NACTA Journal, 47*(3), 18-22.

Hadani, H. S., & Rood, E. (2018). *The roots of STEM success: Changing early learning experiences to build lifelong thinking skills.* The Center for Childhood Creativity. Retrieved from https://centerforchildhoodcreativity.org/roots-stem-success/

Harris, A., & de Bruin, L. (2017a). Secondary school creativity, teacher practice and STEAM education: An international study. *Journal of Educational Change*. Retrieved from https://doi.org/10.1007/s10833-017-9311-2

Harris, A., & de Bruin, L. (2017b). STEAM education: Fostering creativity in and beyond secondary schools. *Australian Art Education, 38*(1), 54-75.

Hoover, T. S, Scholl, J. F., Dunigan, A. H., & Mamontova, N. (2007). Historical review of leadership development in the FFA and 4-H. *Journal of Agricultural Education, 48*(3), 100-110.

Karcher, M. J. (2008). The cross-age mentoring program: A developmental intervention for promoting students' connectedness across grade levels. *Professional School Counseling, 12*(2), 137-143.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, 3 (11), 1-11.

King, J., & Safrit, R. D. (1998). Extension agents' perceptions of volunteer management. *Journal of Extension, 36*(3). Retrieved from https://www.joe.org/joe/1998june/a2.php

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, N.J: Prentice-Hall.

Krishnamurthi, A., Ballard, M., & Noam, G. G. (2014). *Examining the impact of afterschool STEM programs*. Retrieved from http://www.afterschoolalliance.org/ExaminingtheImpactofAfterschoolSTEMPrograms.pdf

Lee, F. C. H., & Murdock, S. (2001). Teenagers as teachers programs: Ten essential elements. *Journal of Extension, 39*(1). Retrieved from https://www.joe.org/joe/2001february/rb1.php

Lerner, R. M., Lerner, J. V., Almerigi, J., Theokas, C., Phelps, E., Gestsdottir, S., Naudeau, S., Jelicic, H., Alberts, A. E., Ma, L., Smith, L. M., Bobek, D. L., Richman-Raphael, D., Simpson, I., Christiansen, E. D., & von Eye, A. (2005). Positive youth development, participation in community youth development programs, and community contributions of fifth grade adolescents: Findings from the first wave of the 4-H Study of Positive Youth Development. *Journal of Early Adolescence, 25*(1), 17-71.

McGinnis, P. (2017, September). STEM integration: A tall order. *Science Scope*. Retrieved from https://s3.amazonaws.com/nstacontent/ss1701_1.pdf?AWSAccessKeyId=AKIAIMRSQAV7P6X4QIKQ&Expires=1528220928&Signature=RVN%2fidP73ycahKoTwOBUzz1miWU%3d

National Academy of Engineering. (2016). *Grand challenges for engineering: Imperatives, prospects, and priorities: Summary of a forum.* Washington, DC: The National Academies Press.

National Education Association. (2012). Preparing 21st century students for a global society: An educator's guide to "the four Cs." Washington, DC: Author. Retrieved from http://www.nea.org/assets/docs/A-Guide-to-Four-Cs.pdf

New York Global STEM Alliance. (2018). *Education framework*. Retrieved from https://www.nyas.org/media/13051/gsa_stem_education_framework_dec2016.pdf

Norman, M. N., & Jordan, J. C. (2006). *Using an experiential model in 4-H*. Retrieved from http://edis.ifas.ufl.edu/4h243

Park, S. & Seung, E. (2008). Creativity in the science classroom: Four Strategies to help students think outside the box. *The Science Teacher, 75* (6), 45-49.

Partnership for 21st Century Skills. (2011). *21st century skills, education and competitiveness: A resource and policy guide*. Retrieved from www.21stcenturyskills.org

Peters, S. J. (2002). Rousing the people on the land: The roots of the educational organizing tradition in extension work. *Journal of Extension, 40*(3). Retrieved from https://www.joe.org/joe/2002june/a1.php

Rehm, C. J. (2014). An evidence-based practitioner's model for adolescent leadership development. *Journal of Leadership Education, 13*(3), 83 -97.

Russell, S. T. (2001). The developmental benefits of nonformal education and youth development. *Focus* [monograph series]. Davis, CA: 4-H Center for Youth Development, University of California, Davis. Retrieved from http://ucanr.edu/sites/uc4-h/files/1231.pdf

Schmidt, A. (2010). The battle for creativity: Frontiers in science and science education. *Bioessays, 32*, 1016-1019.

Simonsen, J. C., Velez, J. J., Foor, R. M., Birkenholz, R. J., Foster, D. D., Wolf, K. J,. & Epps, R. B. (2014). A multi-institutional examination of the relationships between high school activity involvement and leadership characteristics. *Journal of Agricultural Education*, *55*(1), 200-214.

Smith, M. H. (2008). Volunteer development in 4-H: Constructivist considerations to improve youth science literacy in urban areas. *Journal of Extension, 46*(4). Retrieved from https://www.joe.org/joe/2008august/iw2.php

Stedman, N. (2004). Leadership, volunteer administration, and 4-H: Leadership styles and volunteer administration competence of 4-H state volunteer specialists and county faculty (Doctoral dissertation). Retrieved from http://etd.fcla.edu/UF/UFE0004340/stedman_n.pdf

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM. *Journal of Pre-College Engineering Education Research, 2*(1), 28–34. doi: 10.5703/1288284314653

Stouffer, W., Russell, J. S., & Olivia, M. G. (2004). Making the strange familiar: Creativity and the future of engineering education. *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*. Washington, DC: American Society for Engineering Education.

Tate, W. F., Jones, B. D., Thorne-Wallington, E., & Hogrebe, M. C. (2012). Science and the city: Thinking geospatially about opportunity to learn. *Urban Education, 47*, 399-433.

Taylor, A. R., Jones, M. G., Broadwell, B., & Oppewal, T. (2008). Creativity, inquiry, or accountability? Scientists' and teachers' perceptions of science education. *Science Education*. Retrieved from https://doi.org/10.1002/sce.20272

Van Horn, B. E., Flanagan, C. A., & Thomson, J. S. (1998). The first fifty years of the 4-H program. *Journal of Extension, 36*(6). Retrieved from https://www.joe.org/joe/1998december/comm2.php

Van Horn, B. E., Flanagan, C. A., & Thomson, J. S. (1999). Changes and challenges in 4-H. *Journal of Extension, 37*(1). Retrieved from https://www.joe.org/joe/1999february/comm1.php

Notes

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General information about the CYFAR grant program can be accessed online at: https://nifa.usda.gov/program/children-youth-and-families-risk-cyfar. Resources developed by the CYFAR Professional Development and Technical Assistance (PDTA) Center as part of the CYFAR initiative can be accessed online at: https://cyfar.org/

For further information about the CYFAR-funded project highlighted in this publication, contact:

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CHAPTER SEVEN

THE POWER OF BECOMING AWARE OF OUR CREATIVE STRENGTHS AND WEAKNESSES—AND HOW THIS HELPED US COPE WITH LIFE CHANGING HAPPENINGS!

FREDRICKA REISMAN, BONNIE CRAMOND RICK KANTOR & DARREN STODDART

The Setting

Each of the author team experienced/endured a challenge to how we coped with a life changing happening. Each of us are students of creativity – some for more years than the others simply as a function of length of being alive. Others experienced personal trauma and one author responded to a graduate course requirement. This chapter is a written sharing of our participation as a panelist on the 2018 KIE Reisman Diagnostic Creativity Assessment (RDCA) Special Interest Group (SIG) at the 2018 KIE conference in Prague.

Our Stories

Fredricka Reisman

I am the Founding Director of the Drexel University School of Education having spent the past 33 years on faculty. One day, word of a Voluntary Retirement Benefit Policy was disseminated university-wide. Retirement was not on my horizon. However, one evening I was on my couch at home working at my laptop and another retirement announcement popped up. I said to myself that maybe I should at least read it - which I had not done previously. So as I finished reading the retirement policy something unexplainable came over me. I felt a light inside me, very peaceful and I heard Lisa's voice saying, " Mom, perhaps it's time." I had lost my only child, Lisa, six years ago after her 10-year challenge with cancer. When I recounted this experience with friends and colleagues who had known Lisa, they all said, "Freddie, that was Lisa telling you something."

I shared the experience with Sam and Ben, my two grandsons and Lisa's children. They independently responded that they thought I should start to relax and enjoy my other interests. In addition, this was a one-time benefit that included a cash payout of 75 percent of salary, $300 per month toward health benefits for the rest of my life, and a $5000 insurance death payment. There was indication that this would not be a recurring option.

Well, I made the decision to retire and to apply for emerita status. This is where I exercised my creativity. First, I brought to bear the 11 factors that underlie the RDCA. My scores were really high on 10 of them – originality, fluency, flexibility, resistance to premature closure, tolerance of ambiguity, risk taking, intrinsic and extrinsic motivation, divergent and convergent thinking. I was lowest on elaboration—I tend to like the bottom line and lose patience with those who have verbal diarrhea. In sharing my low elaboration score with other mathematics education folk, I discovered a trend that we all shared—we often think in equation type deliberation. Equations represent core ideas not needing elaboration to communicate.

My colleagues were stunned at my unexpected decision to retire and streamed into my office to assess my decision. My main concern was who would continue to grow and mentor the Creativity programs at Drexel. I made the decision to continue teaching two online graduate creativity courses per quarter, continue chairing doctoral committees and at the Dean's request, remain on her Dean's Executive Council that met monthly. Thus, I remained active, although more relaxed as I could pick and choose the extent of my involvement.

I was aware of a pattern of retirees dying soon after retirement. So, in addition to the previous activities, I am writing two books with Drexel colleagues. One colleague is a leader in dyslexia and our book looks at integrating creativity with dyslexia and dyscalculia. The other colleague heads up our sports management and coaching programs and we actually are doing three books that integrate creativity into athletics: for coaches, for athletes and for front office administrators.

I had a great model for active retirement - E. Paul Torrance who had been my mentor and colleague during my 12 years at the University of Georgia. Upon my leaving Georgia for Philadelphia, Dr. Torrance and I continued our friendship – co-authoring three books on learning mathematics creatively with a focus on word problems, place value and prime numbers including fractions and decimals. Our almost daily communication via email and phone calls continued until his death in 2003 at age 88. Thus, the modern father of creativity (as Torrance was known worldwide) enriched my knowledge and applications of creativity and my transition from full time employment to retirement – although I am not discerning the difference.

Bonnie Cramond

This past year has been a very challenging one for me. I lost a dear uncle, and aunt, several friends and a work colleague. Indeed, I felt there was a black cloud over my head. But the most devastating time was last fall when I lost my husband and my son within a 6 week period. My husband had been fighting lung cancer for a year, and we spent the last weeks of his life in hospice. My son had been fighting leukemia for almost five years, so I went directly from hospice after my husband's death to the ICU in the hospital to care for my son during the last weeks of his life.

I was a very active person, had been the Director of the Torrance Center at the University of Georgia, and was a full time faculty member with a busy research and committee schedule. Even while caring for my son and husband, I kept a busy schedule. The late summer and fall when my husband and son got so sick and then died, I was scheduled to speak in Australia, Korea, Taiwan, Malaysia, and Croatia. I cancelled all travel when I saw how critically they both were. But, by the end of that fall semester, I was physically exhausted and emotionally traumatized. I could not concentrate, nor did I care to do so.

I met with my department head and told him that I would be taking a semester of sick leave and then retire. He agreed that I needed some leave time, and after working at the university for 29 years without ever taking any leave, I had many days. He asked me not to decide to retire at that point, but to wait and decide at the end of the semester.

So, I suddenly had a lot of free time and a lot of grief. I had to find a way to fill my time and deal with the grief. That was when the creativity training I had gotten from E. Paul Torrance, the teaching I had done about creativity, and my research on creativity came into play. I decided to express my pain in creative ways to exorcise it. I wrote poetry about my feelings, which served as a catharsis.

I remembered that when I had taken a drawing class years before, it had served as a wonderful oasis during the week from the stress of work. Every Wednesday, from 1:00 to 3:00 I went to the local art center to draw. It seemed that I would take out my materials and begin drawing and before I knew it, it was time to pick up. The two hours passed so quickly as I was in the flow of drawing and lost awareness of time. As much as I loved the class, I didn't take another one because my schedule got so busy.

I also realized that I had not been cultivating friendships during the time I was working and caring for the sick. So, I started a Drink and Draw activity once a week, whereby I invited a regular group of acquaintances to my home to sip wine and sketch. The sketching and companionship gave me something to look forward to every week, and I got to know these women, who became friends.

I also realized that engrossing myself in cooking and gardening were creative outlets that kept me busy, relieving stress and distracting me from my grief. I have enjoyed trying new recipes, improvising, and innovating. The physical labor of gardening was also healthy, tiring, and productive.

These creative activities--writing, drawing, cooking, and gardening—have helped me to cope with my trauma, but I also have been going to a counselor and joined a grief group. These are the things that help me get out of bed each day.

During this semester of sick leave, my 91-year-old mother, who lives with me, started having some physical problems in addition to her worsening dementia, So, in May, when my department head asked for my decision about retirement, I told him that I had decided to do so. This was a hard decision, because, like Fredericka Resimann, I had not been thinking of retirement before that. Much of my identity was tied into being a professor as well as a wife and the mother of my son. I felt that I was suddenly losing so much of myself. However, I was still suffering with trauma and now had my mother to care for. I didn't think that I could do the job well, so I knew it was time to retire.

That was when the department head offered me an innovative solution, which was approved by the new dean. He told me that I still had many days of sick leave left and would lose them when I retired. He also reflected that I have six doctoral students at various stages of completing the degree who still need guidance in completing their dissertations. He offered me the opportunity to work 25% time to help these students finish and take 75% sick leave for the next year. I thought about it: I would have worked with those students anyway because I had a commitment to them; I would have one more year to add to my retirement fund; I would not have to find a new health care plan; and, most convincing, I would not have to clean out my office for another year.

So, creative thinking has helped me fill my time, reduce stress, and deal with the trauma of the deaths of my loved ones. It also helped solve problems by helping me to ease into retirement while assisting my students to finish their degrees. I believe that training people to use creativity is an important way to help them deal with the stresses and trauma that life inevitably deals us all.

Rick Kantor

It is easy to forget that the modern field of Creativity, currently esteemed and in demand, was built on the search for relevant human survival skills in war. Long before there was the Information Age, innovation pipelines running empty, and the 2018 World Economic Forum survey finding creativity is the #3 skill sought in today's workplace, Dr. E. Paul Torrance was teaching the skills of creativity to World War 2 combat Air Force crews at the Air Force Survival Training Program at Reno, Nevada. Creativity, Dr. Torrance discovered, was the defining element found to be critical in the psychology of survivors in war.

" In the survival schools, the goal was to train men to behave effectively in emergencies and extreme conditions."(Personal Communication). "Whenever one Is faced with a problem for which he has no practiced or learned solution, some degree of creativity is required." (Millar, et al).

In 2017, life handed me two extreme opportunities to experience directly how creativity would inform my own survival.

One of Dr. Torrance's own definitions of creativity explains the first event.

"Creativity is the process of sensing gaps or disturbing, missing elements; forming ideas or hypotheses concerning them; testing these hypotheses; and communicating the results, possibly modifying and retesting the hypotheses" (1962).

The missing element in my life was an explanation for why the digital exercise heart monitor consistently showed my aerobic effort in a strenuous cross fit class to be significantly lower than the rest of the class. We appeared to all be performing similarly. Yet my numbers were different. The trainer dismissed the anomaly, for several weeks as a device error. I was skeptical. Enter serendipity, considered by Robinson and Stern to be one of the 6 essential resources of creative accomplishment.

By chance, I attended a friend's annual bocce tournament. Here in Sonoma County, bocce is as common as horseshoes in the Midwest. Just served with wine, not beer. I greeted an avid cyclist guest who is always training for some cycling event. "Ed, how are you?", I greeted him. "I'm getting a little better, but still slow" he replied to my quizzical stare. "Two weeks ago I was rushed to the hospital for emergency open heart surgery. No warning, only the slightest indication that my training numbers for aerobic recovery were shifting slightly. When I saw the doctor who ran a quick test, he put me in an ambulance on the spot and told me I'd be having surgery the next day."

One of the correlates of the creative personality is vigilance, openness to what is present, intuitively responding to information presented, seeing the possibility presented by serendipity, acting and implementing. I immediately thought of my unexplained exercise numbers and wasted no time setting up an appointment for a cardiac stress test. The abnormal results then required an angiogram. The results of that made the convincing case for open -heart surgery. A quadruple bypass. Nothing in my regular check-ups indicated any issues at all. I'm a healthy living, non-smoker, very modest drinker, fit and slim, with no symptoms at all. Not a reason in the world to suspect a problem.

Yet my creative mindset was unconsciously and consciously at work, being curious, seeking explanations, observing the world anew each day without pre-suppositions, continually sharpening my senses and making new connections between seemingly disparate items. Dr. Torrance called his top creative pilots his "wild colts", the ones who thought and acted outside the box. "The Jet Ace is a man who goes out into life and meets it head on." (p. 38)

By February 28th, after 5 cardiology opinions, I completed successful surgery. Recovery and months of rehabilitation are as successful, meaningful and fun as the amount of creative energy you put into them. Since playfulness and laughter are correlates of creativity and hence survival, I made sure the post-operative experience was of my own design and pleasure. Collaboration being an important creative aptitude, I made sure to stay surrounded by caring friends and family.

I was almost recuperated to my previous strength on October 9, 2017 when the wildfires of Sonoma County forced my 2 AM evacuation from my home without notice. Think about this: you have 3-5 minutes to leave everything you own and love, perhaps never to see again. What do you do? If you have a creative mindset, you accept the unexpected challenge and calmly proceed, effectively and decisively.

It would be 9 days of evacuation, or not knowing what would happen, of finding places to stay, places to volunteer to help others, trying to grasp the new reality each day; communicating with a network of support. Accepting that our survival would depend on good decisions, clear thinking that considered all the options. Employing divergent and convergent thinking in every new moment to stay safe and informed.

I was one of the lucky ones who writes this from my house, unscathed. As I thought about the relative ease with which we navigated our circumstances and the obvious risks around us, I could see how creativity is a way of seeing the world as it unfolds and being able to respond appropriately.

The Reisman Diagnostic Creativity Assessment identified which 6 of my creative strengths made survival more likely in both events of 2017:ß

Tolerance of Ambiguity: being comfortable with the unknown; no preconceptions.

Resisting Premature Closure: keeping an open mind, whichever way the winds blow.

Divergent Thinking: generating many solutions and possible ways to proceed when left homeless, unsettled.

Convergent Thinking: Analyze events, evaluate and come to closure.

Risk Taking: exploratory, venturesome, daring.

Intrinsic Motivation: ability to find enjoyment and meaning, personal drive to thrive and survive

There is a misconception, still, that creativity is somehow either a luxury, or the domain of a few but not gifted to many, or it is an artistic expression, or that it is a soft skill. It is all of these things, too. But first and foremost, it is that most uniquely human capability to observe, to assess, to find ideas to develop as solutions and to implement, thereby taking dominion over our circumstance and world. Creativity is how we will manage to survive, however great the threat or challenge. Creativity is how we can prepare ourselves to be ready for anything.

Darren Stoddart

Openness to experience is a key factor in creativity assessments; but being open to experience and being prepared for one are two entirely different things. I travelled to Rarotonga, the capital island of the Cook Islands in the South Pacific in February of 2018 to study creativity there. Prior to deciding to make the trip, I had been in contact with several people on the island, all of whom replied to my initial email in a fairly similar way. They would tell me a mind-bending story about creativity on the island, volunteer to help me out with the paper I planned to write, but end with something along the lines of "but it would be a whole lot easier if you would come here." The stories I was told ranged from the Mäori creation story in which the gods control creativity to descriptions of galleries displaying paintings by local and foreign born artists selling for over $10,000 USD.

Having set out to write a paper to satisfy the requirement of a course in Drexel University's MS in Creativity and Innovation program, travelling to the island was not initially even in my consideration set but the draw of the place and the people there quickly became undeniable. I was awarded a grant from Drexel for the trip and within two weeks I was on my way to the island.

A travelogue would be easy enough to write, Rarotonga is a beautiful and exotic place but I managed to see less than five miles of the place in my six days there. My days were half filled with healthy debates with academics, museum curators, artists, and whenever the opportunity presented itself anyone else that was willing to discuss the workings of creativity there. The other half of the day I spent working alongside a master carver who by his own admission "loves opposition." There was no mental downtime, being open to experience, in the way I felt appropriate required constant mental engagement.

Leaving for Rarotonga I was a person who was fiercely independent, I'd spent hours writing and arguing against Systems Theory, thought of a creator as individual or potentially as a group of individuals, and dismissed divinity as mythology. In just a few short days I found working examples of Systems Theory that were not only important and embraced but very nearly a requirement of life on a small remote island.

I learned that people can't create, they can only innovate. All of the world around us was created either by a deity, group of deity, or cosmic forces, all we do is put it together. It became clear that working alone, in isolation, is arrogant and problematic. The web of all living things became even more clear as I heard stories of talking to trees as equals, and circumstance after circumstance kept piling up to the point that it was impossible for me to say that I had not somehow been set on a course to visit the island and make the connections that I did at least twenty years prior to my trip.

Believe what you will, reject or explain the inexplicable, when I asked the master carver how I could understand everything that was happening to me on Rarotonga he replied "you won't, your European mind won't allow it." I believe that he is right, I can't understand it but I can be open to it, but there is no way that I could have prepared for the lessons in creativity that I received on Rarotonga that continue on in every conversation I have with my new friends.

CHAPTER EIGHT

CREATIVITY AND CONNECTEDNESS ON RAROTONGA

DARREN W. STODDART

Abstract

This paper documents the events leading up to, experiences onsite and the outcomes from, a trip to Rarotonga, Cook Islands in February 2018. The trip was conducted to research the attributes and definition of creativity across a group that included government employees, artists, and academics. Results of the Reisman Diagnostic Creativity Assessment (RDCA) served as an interview guide for the purpose of understanding how the interviewees' views on creativity did or did not align with those commonly held in the West. The Rarotongans demonstrate many unique characteristics that complement creativity including the inclusivity of the community, practicality in their approach, and the de-emphasis of the individual. This paper documents several interviews, artistic production alongside one of the interviewees, and it discusses the potential for relating Rarotongan views to western cultures including increased cooperation, slowing down, and group motivation.

Keywords: creativity, inspiration, artists, group motivation, Rarotonga, Cook Islands

Introduction

This paper may have started in 1995, my wife Tracey and I were married that year at the Bali Hai restaurant in San Diego, California where we lived at the time. After we returned from our honeymoon, I sat down to create our thank you notes. Using what was a nascent World Wide Web, I found the perfect image to use on the cards, it was Tangaroa (Figure 1), the Mäori demi-god of the sea and of fertility. The form of Tangaroa I used on the cards is carved (Figure 2) on Rarotonga, one of the Cook Islands, a place completely unknown to me at the time.

The next pivotal moment in the development of this paper came December 31st, 2017, the day after I received the textbook for my upcoming course at Drexel University entitled *Global Perspectives on Creativity*. After a quick scan of the text, I realized that none of the South Pacific countries were covered. This omission provided me with the potential opportunity to discover something new about creativity in a remote part of the world for my final paper for the course. I searched for "Creativity Polynesian" which led me to the book *Collective Creativity* by Katherine Giuffre (2016), written about the community of artists as she observed them on Rarotonga, an island that related to my Tangaroa thank you cards. My next search was for "Creativity Rarotonga" and that's when the momentum started. I reached out to several people on the island on January 16th to see what kind of connections I could make to support a primary research project. The first response I received was from Sean Dunmurry who wrote "Kia orana Darren, many thanks for your email. I am happy to help as best as I can, bearing in mind we are in the middle of the busy process of completing summer schools and commencing first semester enrollment." This was encouraging enough but then Sean went on to educate me on Te Ao (this world / light) where we humans live, and Te Po (the other world / night) where the Gods live, noting that, "creativity, if you like, is a divine intervention - an inspiration from the gods." On January 17th, I reached out to Dr. Fredricka Reisman, my instructor, to introduce her to the project, and ask if Drexel might have funds available to help support a trip to Rarotonga. In little over an hour, Dr. Reisman had passed along my request to the Torrance Center Board who review funding support requests. Three days later Dr. Reisman informed me that the funds were available, and I booked my ticket to be on Rarotonga from February 10th through the 17th.

Much of my time on the island was spent working alongside the artist Teina 'Uri'uri including carving two Tangaroa. I had my wife, Tracey send me a picture of the previously mentioned thank you card to show to Teina. He commented that, "something had its hook in you a long time ago to bring you here." In the first email I received from my new friend upon my return to the US, Teina wrote: "When you used the Tangaroa image on your thank you cards for your wedding 25 years ago, you committed yourself to coming to see me then." The following text details my trip to Rarotonga, the conversations and interviews I had with artists, educators, and politicians and a series of events that I am yet to fully understand.

The Cook Islands and Rarotonga

Over 2800 years before my visit, expeditions from French Polynesia made the first landfall on Rarotonga. In the eleventh century C.E., settlers from other parts of Polynesia built Te Are Nui o To'i, now known as Ara Metua, the "road of ancestors", which runs around Rarotonga. These first permanent settlers were conquered by raiders from Tahiti and Samoa, "with this conquest were erased almost all memories about the building of great road" ("Ara Metua", n.d.). This paved road supported movement of goods, a path to sacred areas, and unfortunately easy transport for the warring tribes. These wars were the normal state for the island until the arrival of the European missionaries. The first documented landing on Rarotonga by Europeans was in 1820 by the ship the Cumberland, captained by Philip Goodenough. Goodenough was a tradesperson, not a missionary, with that said, either he or his crew "told [the Mäori] about God, whose name was Tiova (Jehovah) and Tititarai (Jesus Christ). He was the great God of heaven and of all countries" (Maretu in Gill, 2017). Goodenough's time on Rarotonga had a disastrous and deadly end due to their general disrespect, the theft of property and abuse of native women by the crew. The next European encounters led to a radically different outcome.

The first true missionary to Rarotonga was John Williams of the London Missionary Society who had been active for two decades in the Society Islands. Williams determined that he could spread his religion faster by training Polynesians "whom he felt could establish contact with their own or related peoples quite easily" (Gilson, 1980). Williams and his missionaries converted Rongomatane, a high chief of Atiu who in turn provided sailing directions to Rarotonga. The mission included Tapaeru, a Rarotongan abducted by Goodenough and left on the island of Aitutaki. It was the missionary Papeiha, who in 1823 decided to stay on Rarotonga. "Papeiha accomplished more in Rarotonga in two years than the English missionaries in Tahiti had in twenty" (Gilson, 1980). Papeiha convinced the Rarotongans to destroy their idols and other artifacts. When nothing disastrous happened, he was able to convert them and then broker peace between the tribes. Papeiha convinced the converted Christians to live in Avarua, which became the capital of Rarotonga and the Cook Islands.

Rarotonga, the capital of the Cook Islands, is a 67 square kilometer island. about 1/3 the area of Washington D.C. I flew 4,692 miles southwest from Los Angeles to reach it. To triangulate its location, you could look 2,940 miles due south of Honolulu, Hawaii, and 1,868 miles northeast of Auckland, New Zealand. The average high temperature from season to season ranges only 7 degrees Fahrenheit, from 77 up to 84.

According to the 2011 Cook Islands Census, Rarotonga is the most populous of the 15 islands, the 13,044 residents make up seventy-five percent of the total population of the Cook Islands. The gender split is more or less equal, the median age is 29, making it lower than any U.S. state. There are 63 residents per square kilometer on the Cook Islands—Tennessee, South Carolina, and Georgia have similar population densities. Thirty-one percent of the population of Rarotonga was born outside of the Cook Islands, seventy -six percent of the population is comprised of Cook Islands Mäori. Rarotonga has the highest education rates of all the Cook Islands, sixty-five percent of the population having attended secondary school comprised of grades seven through 13. Basic education ends at grade 11 and most students end their education there rather than completing secondary school. Twenty-one percent of the working age population is employed as "Service Workers, Shop and Sales Workers". The average worker earns $17,695NZD or $12,842USD per year with men earning more than women. Amongst the population over fifteen years old, there are 1,093 performers, 192 composers, 181 choreographers, 198 traditional medicine practitioners, 132 carvers, 3,416 spectators, 226 participating in other cultural activities, and 3,269 not participating in cultural activities. Census respondents were able to select as many as were applicable from a list of cultural activities. By using the lowest possible number of unique individuals, the performers, at least 21% of the population of the island take part in cultural activities and over 66% are spectators.

Polynesian arts are evident everywhere on Rarotonga, regional black pearls are made into jewelry, carved wooden canoes, drums and idols like Tangaroa sit next to ornate Tīvaevae quilts and handmade hats, while musicians and dancers perform traditional dances. The arts and crafts of Rarotonga have been well documented since the arrival of the Europeans in the early 1800's. Song and dance, wood carving, fiber weaving, tattooing and other art forms were present before the arrival of the Missionaries. These works were shipped back to Europe as museum pieces by the London Missionary Society. The Mäori carving tools were incompatible with Christianity, "after the conversion to Christianity, the ceremonial adzes ceased to function as religious symbols, but their unique form and neat carving and lashing made them interesting art objects to the settlers and visitors of another race" (Buck, 1944, p. 500).

Creativity on Rarotonga

Today, the arts are alive and well on Rarotonga, from handicrafts to what Sean Dunmurry would describe as paintings exhibited at "the kind of show where a few people stand around eating wine and cheese with the backs to the exhibit." The native Rarotongans do not appear to have any use for the latter. What may come as a surprise though is that none of the artists I met consider themselves creative. As a matter of fact, in their belief, the notion of a human being creative is laughable. Consider these statements from Teina "Innovation can be done by man [not creativity]," "Men can produce, not create," and "Create is a wrong word because it ties to God." This view also exists in India where it is thought that "since creativity involves originality and novelty, it is sometimes considered to be a gift of God, but discoveries and inventions clearly imply the role of human effort." (Misra, Srivastava, & Misra, in Kaufman & Sternberg, 2006). Similar ideas exist in Africa where creativity "is a gift from God and we make it better by care" (Mpofu et al. in Kaufman & Sternberg, 2006), and in Poland where "Creativity was originally conceived as a divine activity, inaccessible for humans, who at most could aspire to skills, mastery, and craftsmanship." (Nęcka, Grohman, & Slaboz, in Kaufman, & Sternberg, 2006). For clarity, this view of creativity was part of the Western European tradition up until the Renaissance. At that time, we "put the individual human being at the centre of the universe above all gods and mysteries and there's no more room for mystical creatures who take dictation from the divine, and it's beginning of rational humanism and people start to believe that creativity came completely from the self of the individual" (Gilbert, 2009). Prior to the Renaissance it was believed that, "God has all of the creativity, the world has none. The creative God is not present in the creatures, but is their external creator and controller" (Griffin in Mitias, 1985, pp. 65). When a God leaves Te Po to touch a human while they are working, the Rarotongans call this inspiration, divine involvement is present whenever inspiration occurs.

Teina explained the concept of inspiration well with a story about building and launching a seafaring canoe. When a carver cuts down a tree, a simple prayer is made. A paraphrased version of the prayer would be; "My brother, the tree, I have to take your life and I'm sorry for that, I will build a canoe that will be beautiful and will be used to get food for my family." There is another prayer made with the first cut of the carving. A special Taura (rope) is made from a sacred plant that becomes the symbolic umbilical cord for the canoe. One end is buried on shore while the other is tied to the canoe. When cutting the cord to send the canoe off to sea, the carver makes a third prayer. At this point, there should be a little bit of rain and a rainbow, and then a second rainbow when it is out to sea. I asked Teina "is that proof of divine intervention" to which he replied, "you tell me, I don't know what else it could be." I went on to ask, "how can a person get inspired?" Teina replied, "You don't look for inspiration, it finds you." Tugnane Majaora explained the concept this way, "When you have an idea, you do get inspired by something that you have no idea where it came from." Tuiara Pere reinforced them both by saying, "there is a spiritual reason that you create art, you can't explain it." My inability to grasp the Rarotongan concept of inspiration as an agnostic, humanistic, individualistic papa`ā (one of European descent) was acknowledged by both Teina who said, "You don't even understand the English language! Some Europeans don't know their own words properly." and Sean, "The mojo concept is something similar to inspiration, surely you can relate to that." To them both I said, "I don't understand it, but I can accept it."

While searching for understanding, I presented the concept of the muse to Teina. The muse could be as a potential analog to his idea of inspiration. Teina shot down the notion of the muse; the muse to Teina is just a vehicle that the Gods have flown through to the receiver. The "proper word" for the Western notion of inspiration, might be impulse: "a sudden strong and unreflective urge or desire to act" (Impulse [Def 1.], n.d.) Inspiration by comparison is "a divine influence or action on a person believed to qualify him or her to receive and communicate sacred revelation" (Inspiration [Def. 1a], n.d.) My inquiries about words like "impulse" led back to divinity, not to an individual. I never found an English word to describe creativity that would sever the tie with the divine. The word creativity is not misunderstood on Rarotonga, it simply has a different meaning. The artists on Rarotonga use the word 'innovation' in the way the West uses 'creativity'. Tere Kavamani, a government official, shared the following thoughts, "Tourists should understand that creativity [as Westerners use the word] is a new concept here, tourists need to understand originality instead." Tepaero Roro, an educator provided a view somewhat closer to that of the West when she said "No one stops to think about creativity, that's for the rich, but everyone here is creative... they have to be! [For example] Elastic for pants was made from bike inner tubes. This kind of resourcefulness needs to be celebrated."

As noted in the census data, the Cook Islanders have a very high incidence of reporting direct involvement in the arts. There is reason to believe that these numbers are under reported and that the number of people is higher, at least amongst the native Rarotongans given the communal nature of creative or if you prefer, innovative production. The ego is suppressed, or kept in check by the Rarotongans, 'Arerangi Tonga points out that "the individualism of US culture contrasts with our more communal approach. We work together in schoolwork, lagoon net fishing, making umu (earth ovens), working in the gardens or preparing costumes for cultural performances. The close-knit communal effort unites us in achieving our goal" (Tonga in Crocombe & Crocombe, 2003). Gell in 1998, offered a reinforcement, "it is much more appropriate to treat 'collectivities' rather than individuals as units of style". One example of this communal artistic product is Nuku.

Nuku is a pageant held in celebration of Christianity's arrival in the Cook Islands. Communities gather around the various parishes of the Cook Islands Christian Church (Figure 3) to create humorous, unscripted, theatrical performances based on Biblical stories. "The performance of Nuku evolves through collective decision making and the inclusion and cooperation of the people in the village" (Gragg in Dixon, Crowl, & Crocombe, 2015). In talking about the collective nature of creative production like Nuku, Sean said "no art work is the production of a single composer or artists but is worked on by groups of people and becomes their creation. So, art and creativity are very important ways of manifesting and reinforcing group identity and solidarity." The artist Tugnane Majaora has developed an interesting way of being a part of the Nuku community. She does this through not only her writing but also through her paintings and sculptures. The clearest example of Tugnane's integration with the Nuku is her Jonah and the Whale series. Over three paintings she explores "the idea of the viewer sometimes feeling involved in the Nuku and at other times watching the Nuku" (Gragg in Dixon, Crowl, & Crocombe, 2015). She becomes not only a documentarian, or observer but also a performer. She elaborated on the Nuku through her painting. In her own words she was "shifting from an audience point of view to being involved as an actor" (Gragg in Dixon, Crowl, & Crocombe, 2015.) In "Jonah Resisting being Swallowed" two fishermen in a makeshift boat have their feet protruding through the bottom of the hull. Jonah spreads his legs wide across the open maw of the whale. Tugnane's decision to paint the Nuku as it was, with performers in a fake ramshackle canoe, shows a connection to the event rather than an interpretation of it. The second painting, "The Whale Looks Down" shifts the viewer to an imagined perspective of being the whale. The whale is both stylized and traditional in design. It looks somewhat like the eye of a carved Tangaroa or the lines visible on the lower jaw of a blue whale. The whale looks down not on six fishermen but on six Nuku performers. The final painting in the series, "Jonah Falling into the Whale's Stomach" shows Jonah with his face, feet, hands, and rear end all facing the viewer as he descends into the whale's stomach. This scene and perspective seem unlikely to have been possible at the actual event. Through her depiction of the Nuku, Tugnane becomes a part of the Nuku. She stays a part of the community instead of operating outside of it, or in defiance of it as is the contemporary Western tradition.

An outrigger canoe model made in Teina's shop (Figure 4) and brought home with me is another example of a communal project. The construction of the model started with Teina asking me to rough cut a piece of wood that he identified. Teina next used a planer to square up the board to start a carving. Using both a small chainsaw and manual carving tools he began to form the shape of the hull. As the form started to take shape, he enlisted the help of an apprentice to build up what would become the upper stern section. The apprentice took the piece and continued some shaping and initial sanding. The day ended with me sanding the outside of the hull. The next morning when I arrived Silivia, Teina's wife, was sanding the hull. She had carved the float either the prior evening or quite early that day. Mid-morning, an American couple stopped by to pick up a drum they had commissioned from Teina who was not there at the time. The couple inquired with Silivia about what she was working on and she said "it's his canoe" referring to me. After they left I asked Silivia why she said it was my canoe when I had done so little of the work on it. Her response seemed to suggest that it was mine because I would be the owner, not that it was mine because I was one of the participant carvers. This is consistent with the old traditional of naming a spear after the spear owner, not after the carver of the spear. The canoe hull and float were sanded and stained for transit by Silivia, Teina, and myself. Teina lashed the hull, and the canoe came with me to the US in pieces. The final assembly for the canoe required creating posts for the float and lashing the whole thing together. The canoe was completed with the help of my wife and daughter. This type of communal workflow was typical of Teina's shop, he also stays connected to the larger community by working inside traditions.

The word "creativity" means "art" for many people. Art related skills, when more refined, are somehow thought to indicate a higher level of creativity rather than a higher level of craftsmanship. This is true not only with laypeople but also with academics and "experts." A very clear example comes from Glăveanu in a 2014 article when he shows his own bias, "the domain of art is highly institutionalized and it has been like this for centuries, actively selecting the few who possess talent, and excluding the great majority of people who are less creatively endowed." and the laypersons "when asked to rate different professions, for instance, it becomes obvious that the arts (painter, musician, writer, actor) are scored generally higher and faster in terms of creativity than other types of occupation." Focusing first on "creativity means art", creativity is seemingly everywhere in Rarotonga. Galleries large and small, handicraft shops, and a thriving open-air market dot the main road around the island, but particularly so in and around Avarua. This, I presume, is in direct response to the fact that tourism is one of the largest contributors to the Cook Islands economy.

The Cook Islands government has financially supported and tied itself to cultural development since its independence from New Zealand. In his book Nation and Destination: Creating Cook Islands Identity, Jeffrey Sissons covers these pendulum swings in great detail. Thomas Davis who was elected to office in 1978 took to "pointing out that so much had already changed through the influence [of] Christian teaching, commerce, technology and travel, and that if it had not been for tourism many aspects of 'culture' would no longer exist" (Sissons, 1999) even going on to say "the cultural thing is moving, it's pretty limited, but more important is to improve the economy." When the economy depends so heavily on tourism, and tourists are there for the culture, and the culture is represented by suitcase sized art products, Davis' comment seems out of step. The government connection to cultural preservation is most apparent in dance. Large regional dance exhibitions have been formed and winning dance troupes regularly travel internationally for the purpose of promoting Cook Islands tourism. As an aside, the group of artists interviewed for this paper are all working independent of government, their interest in preserving Rarotonga culture comes from a deeper, non-commercial place. Certainly, they sell their work, some for large sums of money, but that money gets shared and spent locally for the apparent benefit of all. Living a life of excess and being accepted in Rarotonga are completely incompatible.

Stepping away from the "creativity means art," and the influence of government, and tourist monies, creativity in a broader sense is evident in every corner. There is only one significant hardware store, owned by CITC (Cook Islands Trading Company). The store has limited hours and selection when compared to a US hardware chain. When something breaks, out of necessity, Rarotongans find a creative way to repair it. Rarotongans don't just throw away a small appliance in some far-off landfill and go to the super center to buy a new one, they repair or repurpose it. It's quite possible to see a toaster oven converted to a fruit dehydrator, and in fact, I helped do that (Figure 5). Teina's sister, who lives next door to him on Ara Metua, has a fruit stand that runs unmanned, on the honor system. Teina happens to have a lot of bananas which he dehydrates using the power of the sun to sell at his sisters stand. The solar dehydrators he built are ineffective during the rainy season, so he was getting stuck with bananas good for little more than fertilizer. Teina also happened to have a working toaster oven. One afternoon, during a break from carving, I offered to turn the oven into a dehydrator for him. He agreed to my suggestion and I set to work cutting it open and simplifying the circuits. Once it had it's top removed and the inner oven exposed I built (a particularly bad) wooden tray and attached some window screen to it as a proof of concept. When I came back the next morning, Teina and his apprentice had six or more (very well made) trays on top of the oven. There was also wind guard around it and what must have been one hundred bananas drying inside. After one short circuit due to a drain issue, we, as a team of three, had a very functional system and another example of a seamless and collaborative work flow. I asked Teina if this was an example of creativity, of course it wasn't… it was innovative and as Sean would say "every form of expression is the group." It is also not a unique story, what gets celebrated as a creative DIY ethos in the US, is just life on Rarotonga.

Creativity Research on Rarotonga

Considering the small population and remoteness of the Cook Islands, there has been a significant amount published about creativity. The work has focused on the arts and its connection to the culture. The majority of the texts were written or edited by natives or long-term residents who immersed themselves in their topic on a local level. The only examples of large scale qualitative studies that I came across were sponsored by the government. The national census is a prime example. According to several people I spoke with, it is not common to see a survey of any sort. As an outsider, I experienced no hesitation on the part of residents of the island to share their thoughts and stories, in depth interviews and observation techniques were well aligned with the culture on Rarotonga. Speaking with a couple of people involved with the education system "off the record," it does not appear that anything like the Torrance Tests of Creative Thinking have been deployed in the school system. There are higher priorities, like rebuilding usage of the Cook Islands Mäori language which had been neglected as a topic for a long period of time. There is another key reason for the lack of this type of testing though, and that is the aversion to breaking the community into individuals.

I used a discussion guide for the interviews (Appendix A), it included the categories from the Reisman Diagnostic Creativity Assessment (RDCA): Originality, Fluency, Flexibility, Elaboration, Tolerance of Ambiguity, Resistance to Premature Closure, Divergent Thinking, Convergent Thinking, Risk Taking, Intrinsic Motivation, and Extrinsic Motivation. I was able to use this as a tool for lengthy conversations with both Teina and Tugnane. There was resistance on both of their parts to the nature of the questions, designed in my case to understand "What is Creativity?" but developed initially to measure various aspects of an individual's creativity. The following are some of the key comments from the discussions.

Originality:

1. "This is Tupuna, like an ancestor." - Teina

2. “This is something that is the property of the Maori people. Indigenous versus imported.” – Teina
3. “I don’t think there is anything new, there’s just a different way of doing it. Originality might just be in the eye of the unexposed viewer.” – Tugnane
4. “Here [in Rarotonga] originality is just expressing something in a different way.” - Tugnane

Fluency:
1. “This comes from Ta’unga, an expert.” – Teina
2. “This has nothing to do with creativity, this is repetition, not creativity” – Teina
3. “With ‘fluency’ it depends on what is required of you. You have to be interested in an idea.” - Tugnane

Flexibility:
1. “This doesn’t make sense, why would I generate lot’s of different ideas when I already know what you want?” - Teina
2. “This must mean the larger area you cover when tackling a problem the better off you are.” - Tugnane

Elaboration:
1. “All ornamentation has a purpose, beauty is a side effect.” - Teina
2. “Maybe I do this when I swap one word for a better word when I work on a poem.” - Teina
3. “A lot of time when adding to an idea it’s just to explain it better.” - Tugnane

Tolerance of Ambiguity:
1. “This is Aka Koromaki” (to tolerate, be patient) - Teina
2. “A person that isn’t tolerant of ambiguity is not creative, they’re not an artist.” - Teina

Resistance to Premature Closure:
1. “When I look at a log and I know I am going to make a Tangaroa, I only see a Tangaroa.” Darren “But what if you see a bird in the wood while you’re carving?” Teina “I wouldn’t because it would not be there.” - Teina
2. “This must mean that you continue to push.” - Tugnane

Divergent Thinking (Note: This was an easily understood concept, but it is a single inseparable process with Convergent thinking):
1. “Some people who have travelled have that ability.” - Tugnane

Convergent Thinking (Note: The word "converge" did not seem to translate well):

1. "You can't converge without experience and knowledge." - Teina

Risk Taking:

1. "This is Timata, to try." - Teina
2. "I take risks because I am over confident" - Teina

Intrinsic Motivation:

1. "I want to perpetuate my ancestry and leave a legacy. We are a unique race of people and I'm proud." - Teina
2. "When I was younger I was attracted to the idea of being in the Tate Museum" - Tugnane

Extrinsic Motivation (Note: This most certainly includes divine inspiration):

1. "Doing less than your best work when hired would be a sin, why would a commission be less beautiful?" - Teina "I pride myself on being pretty good, doing anything less is an insult to myself" - Teina
2. "Appreciation by the receiver is part of the price." - Teina

As we talked through each question, Tugnane physically pulled back at one point and said, "this is so judgmental isn't it? It is so judgmental… putting people into boxes… making sure that everybody is in the right box. It's eerie, almost ugly," describing in a visceral way, how unnatural it feels to a Rarotongan to break apart the group. In order to conduct further creativity research on Rarotonga, significant translation of the RDCA or TTCT would be needed. The goal should be to align the tests with the uniqueness of the Mäori language, and with the Vaerua Tā'okota'i, the united spirit of the people. The first step of this process should be a translation of the concepts of the RDCA (or TTCT) into the Mäori language. This is not because there are any barriers to understanding, but because the concepts need to match the place better than the English language is capable of.

The following translations have been developed with Teina, further validation of the terms is encouraged before any deployment.

RDCA Category	Mäori Term	Literal Translation
Originality	Angaanga Mou	To work - Catch hold of
Fluency	Tukatau	Fluent (as in language)
Flexibility	Ukauka	Sway to and fro
Elaboration	Akaravarava'anga	Enough - Fragment
Tolerance of Ambiguity	Akakoromaki Pāpūkore	To tolerate - Uncertain
Resistance to Premature Closure	Tāpū O Keu Kore I Te Tuku Vave I Te Au	Resist - Unwilling - Premature - Surrender
Divergent Thinking	Mānakonako Takakē	Thinking - Different/ Foreign
Convergent Thinking	Mānakonako Taokotai	Thinking - United
Risk Taking	Timata	To attempt
Intrinsic Motivation	Arataki Mei Roto	To guide - From – Within
Extrinsic Motivation	Arataki Mei Va'o	To guide - From – Outside

Table 1: Potential Mäori Translations of RDCA Categories

Creativity on Rarotonga Compared to the Western View

In Rarotonga, creativity as a concept, at least with the group of individuals I met with, demonstrates the following strengths:

1. There is a high level of inclusivity of process - Artists and craftspeople collaborate in all that they do. This can be seen in the way that Tugnane connected with the Nuku performers, the way Tuiara uses the shapes and forms from centuries if not millennia of Rarotonga artisans, or the collaborative nature of the work in Teina's shop.
2. Practicality - Living on a remote island limits the resources that are immediately available. On Rarotonga this has spawned a strong, practical, and creative repair culture. Even amongst the artists on the island, decisions are made about the media to use based on availability. Tuiara majored in photography in college in New Zealand but became a painter when she moved back to Rarotonga because

there was no infrastructure to support a photographer. Another clear example comes from the fact that Teina carves exclusively from local wood and stone.

3. Deemphasized individual - Regardless of personal theology, humility associated with creativity, driven from something bigger than the individual has its merits. It should be noted that the individual recedes but doesn't disappear. This is a unique place for the individual against the isolated artist stereotype and a traditional brainstorming session where the process can homogenize creativity to the point of irrelevance.

The concept of creativity on Rarotonga is not without its weaknesses, factors that could act as saboteurs to the people and to the culture. This is not to suggest that anyone or anything there needs to change, to do so would upset the balance of the place in unpredictable and disastrous ways. Those most invested in understanding creativity on Rarotonga, particularly as it relates to the tourist economy should consider:

1. The risk of artificiality - Western culture has warped, co-opted, and diluted the creative output of Rarotonga. From the destruction of the artifacts dictated by the missionaries, to the international airport and all the tourists it brings, to Survivor Season 13 - Cook Islands. Tourists by the tens of thousands buy an artifact of Rarotonga (often made in Asia), see a dinner show (that is cabaret), or live like a local (in a foreign owned hotel). Rarotonga will remain in a constant struggle to protect its authenticity given its reliance on tourism.
2. "Locals Only" - The culturally insular nature of Rarotonga may prevent growth in the creative community. This conflict is well documented in Giuffre's Collective Creativity (2016). What the Rarotongans should consider is that like the growth of a Cook Island pearl, sometimes it takes a bit of irritation to initiate something beautiful. There are several active "European" artists on Rarotonga that don't benefit from the skill, experience, and knowledge of the locals. The locals prevent their own growth when they reject the "outsiders".
3. Lack of common language around the term "creative" - Theological implications create even more issues than art bias. While some of the interviewees were comfortable with the term "creativity" and used it in a Western way, others reject this notion. The definition of the term has been notoriously difficult to agree on throughout history and across the globe. The view of some Rarotongans that creativity is the work of God/The Gods and not even possible by humans makes this situation even more challenging.

Discussion

The unique Rarotongan definition of creativity can be applied in Western organizations and civil society in myriad ways. The benefit of doing so may not be immediately apparent, perhaps not ever apparent to a "European". At one point during my trip I asked Teina what brought us together, after we spent some time debating it I asked, "How I am supposed to understand this?" to which he replied "You Won't. Your mentality will not accept it, the way you Europeans think will not make it possible." This inability to comprehend another world view will limit the adoption of the strengths of the Rarotongan way.

One suggestion for an adoptable behavior would be connecting on "Raro time," slowing down. the "porch culture" of talking and talking and talking. There were benches along Ara Metua for hundreds of years, these benches provided the place to consult and collaborate. This is an important part of life on the island. During Kathy Giuffre's time on Rarotonga she," spent countless hours just hanging around with people and talking -- not formal interviews and not particularly about my research questions (although a lot of what was said in those conversations was really important to me in figuring out what I wanted to say about my research questions)." My experience was very much the same as Giuffre's. Time building connections was always time well spent. The interviewees and I exchanged several in depth emails after my return to the US. We've expanded on topics, clarified points, and deepened our connection. Slowing the pace of the contemporary organization to connect as a whole in a meaningful way would build healthy and holistic cultures.

Stronger communities could be formed using a story Teina shared of five fisherman with me. In the story three of the fishermen catch a fish while two return to shore empty handed. It is Rarotongan tradition that the three fish get split amongst the five fishermen. The worst part of the fish goes to the ones that caught the fish while the best part goes to the ones that did not. The moral of the story is that everyone needs to eat, and you can never know when you may return to shore empty handed. Imagine the small family owned bakery, every family member helps to support the business doing whatever it takes to do so. The family would learn new skills, build trust and respect for each other, and ultimately share in the success of their collaboration. The next evolution of this might look like Teina's shop, where a stranger from thousands of miles away can contribute in some small way to the work at hand, all the while supported by the regular team as they work together in harmony. What might the large enterprise born from this concept look like? How would they define success? Would it be imaginable to be so fluid in a place where regulations, taxes, and codes dictate so much of what is possible? Rather than dismissing this as a model incompatible with a market driven economy, becoming more communal, more trusting, and more humble is a very real possibility and a choice that people can make.

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References

Alexeyeff, K. (2009). Dancing from the Heart: Movement, Gender, and Cook Islands Globalization. USA, University of Hawai‘i Press

Ara Metua - Ancient Polynesian Road. (n.d.) Retrieved March 15, 2018 from: http://www.wondermondo.com/Countries/Au/NZ/Cook/AraMetua.htm

Buck, H. (1944). Arts and Crafts of the Cook Islands. Honolulu, HI. Bernice P. Bishop Museum

Cook Islands Census (2011). Census of Population and Dwellings: Main Report. Retrieved March 15, 2018 from http://www.mfem.gov.ck/images/documents/Statistics_Docs/5.Census-Surveys/4.Census-Report/2011_Cook_Islands_Population_Census_Report.pdf

Crocombe, R. & Crocombe, M., (2003). Akono’Anga Mäori: Cook Islands Culture. Suva, Fiji. Institute of Pacific Studies

Dixon, R., Crowl, L. & Crocombe, M.T. (Eds.). (2015). Cook Islands Art and Architecture. Suva, Fiji. USP Press

Gell, A., (1998). Art and Agency: An Anthropological Theory. New York, NY. Oxford University Press

Gilbert, E. (2009) Your Elusive Creative Genius. Retrieved from: https://www.ted.com/talks/elizabeth_gilbert_on_genius/transcript?quote=90

Gill, W. (2017). Rarotonga Records: Being Extracts from the Papers of the Late Rev. W. Wyatt Gill, I.L.D. London, England. Forgotten Books

Gilson, R. (1980). The Cook Islands 1820-1950. Wellington, New Zealand. Victoria University of Wellington

Giuffre, K.A., (2016). Collective Creativity: Art and Society in the South Pacific. New York, NY. Routledge

Glãveanu, V. (2014). Revisiting the “Art Bias” in Lay Conceptions of Creativity. Creativity Research Journal, 26(1), 11-20.

Hiroa, T., (1944). Arts and Crafts of the Cook Islands. Honolulu, HI. Bernice P. Bishop Museum

Impulse [Def. 1]. (n.d.). In Oxford Living Dictionaries. Retrieved March 15, 2018 from: https://en.oxforddictionaries.com/definition/impulse

Inspiration [Def. 1a]. (n.d.) in Merriam-Webster. Retrieved March 15, 2018 from: https://www.merriam-webster.com/dictionary/inspiration)

Kaufman, J. & Sternberg, R., (2006). The International Handbook of Creativity. New York, NY. Cambridge University Press

Kauraka, K., (1987). Dreams of a Rainbow. Suva. South Pacific Creative Arts Society

Lesser, E., Ransom, D., Shah, R., & Pulver, B., (2012). Collective Intelligence: Capitalizing on the Crowd. Somers, NY. IBM Global Services

Mitias, H., (1985). Creativity in Art, Religion and Culture. Amsterdam, Netherlands. Editions Rodopi B.V.

Rosendberg, L., Baltaxe, D., & Pescetelli, N. (2016). Crowds vs Swarms, a Comparison of Intelligence. 2016 Swarm/Human Blended Intelligence Workshop (SHBI)

Sissons, J. (1999). Nation and Destination: Creating Cook Islands Identity. Suva, Fiji. USP Press

Appendix A
Discussion Guide for Interviews on Rarotonga

Discussion Guide Section:
What do these concepts mean to you?
1. Originality - (Unique and novel)
2. Fluency - (Generates many ideas)
3. Flexibility - (Generates many categories of ideas)
4. Elaboration - (Adds detail)
5. Tolerance of Ambiguity - (Comfortable with the unknown)
6. Resistance to Premature Closure - (Keeps an open mind)
7. Divergent Thinking - (Generates Many Solutions (related to fluency))
8. Convergent Thinking - (Comes to closure)
9. Risk Taking - (Adventuresome)
10. Intrinsic Motivation - (Inner drive)
11. Extrinsic Motivation - (Needs reward or reinforcement)

1. Which of those traits do you think are important or unimportant? Why
2. If a person showed signs of all of those traits what would you call them? Why
3. Is creativity important? Why?
4. Does creativity require a judge or judges? In other words, does it matter what anyone except the creator thinks?
5. How do creative things get recorded and distributed? Is it important to record and distribute a creative idea?
6. Can one person be more creative than another?
7. (In museum or while looking at creative object) What makes this object or solution creative?

Discussion Guide Section 2:
1. How do you define creativity?
2. What does it mean to be creative?
3. Has anyone ever helped you to become more creative or provided you with tools to become more creative?
4. Have you ever helped someone else to become more creative or solve a problem in a creative way?
5. Would you say that creativity is important to life in the Cook Islands / on Rarotonga?

6. What are some of the most creative things in the Cook Islands / on Rarotonga?
7. Please provide an example of creativity in the Cook Islands / on Rarotonga that is not related to arts and crafts but to some other aspect of life like education, business, church services, etcetera?

Appendix B

Figure 1. Thank You Card. Thank you card sent to Stoddart wedding guests and friends.

Figure 2. Tangaroa. Hand carved Tangaroa.

Figure 3. Avarua CICC - Ziona Tapu. Avarua CICC - Ziona Taput “Holy Zion” and adjacent cemetery, built 1853.

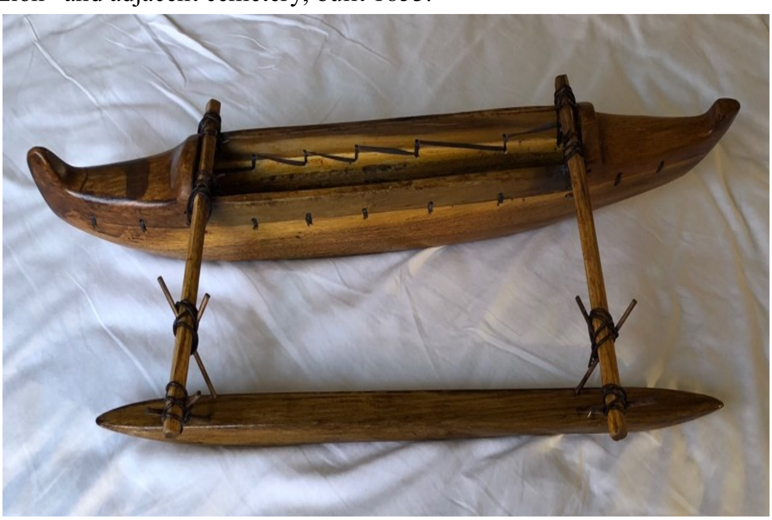

Figure 4. Carved Canoe. Canoe carved from Rarotongan rain tree wood.

Figure 5. Dehydrator. Modified toaster oven and dehydration trays.

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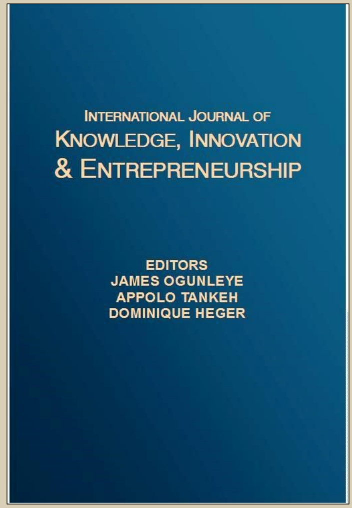

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