The Routledge Companion to Music, Technology, and Education

Edited by Andrew King, Evangelos Himonides, and S. Alex Ruthmann

THE ROUTLEDGE COMPANION TO MUSIC, TECHNOLOGY, AND EDUCATION

The Routledge Companion to Music, Technology, and Education is a comprehensive resource that draws together burgeoning research on the use of technology in music education around the world. Rather than following a procedural how-to approach, this companion considers technology, musicianship, and pedagogy from a philosophical, theoretical, and empirically-driven perspective, offering an essential overview of current scholarship while providing support for future research. The 37 chapters in this volume consider the major aspects of the use of technology in music education:

- Part I. **Contexts.** Examines the historical and philosophical contexts of technology in music. This section addresses themes such as special education, cognition, experimentation, audience engagement, gender, and information and communication technologies.
- Part II. **Real Worlds.** Discusses real-world scenarios that relate to music, technology, and education. Topics such as computers, composition, performance, and the curriculum are covered here.
- Part III. **Virtual Worlds.** Explores the virtual world of learning through our understanding of media, video games, and online collaboration.
- Part IV. **Developing and Supporting Musicianship.** Highlights the framework for providing support and development for teachers, using technology to understand and develop musical understanding.

The Routledge Companion to Music, Technology, and Education will appeal to undergraduate and post-graduate students, music educators, teacher training specialists, and music education researchers. It serves as an ideal introduction to the issues surrounding technology in music education.

Andrew King is Head of Music at the University of Hull, UK, where he has held numerous senior leadership roles such as Deputy Dean (Learning & Teaching) and Associate Principal. He is Editor of the *Journal of Music, Technology and Education*.

Evangelos Himonides is Reader in Technology, Education and Music at University College London, where he currently leads the post-graduate program in Music Education. He is a Chartered Fellow of the British Computer Society.

S. Alex Ruthmann is Associate Professor of Music Education and Music Technology in the Steinhardt school at New York University. He also served as President of the Association for Technology in Music Instruction, is currently Associate Editor of the *Journal of Music, Technology and Education*, and has served as Chair of the Creativity special research interest group of the Society for Research in Music Education.

"It was with great pleasure that I became acquainted with this edited volume that draws together valuable insights across a range of topics related to music, technology, and education. Because it fills a much needed gap in the literature, this comprehensive, insightful, and unique volume will be applauded by music educators internationally."

—Gary McPherson, *Ormond Professor and Director, Melbourne Conservatorium of Music, the University of Melbourne, Australia*

"This volume is a testament to our growing understanding of technology and its role in music learning. The editors have assembled a powerful set of writings that on the one hand provide a badly needed conceptual frame for music technology and education, and on the other offer dramatic and meaningful examples of practical usage, written by some of our finest scholars. Voices from engineering and computer science are welcome additions."

—Peter R. Webster, *Scholar-in-Residence, Thornton School of Music, University of Southern California, USA*

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CONTENTS

FIGURES AND TABLES

Figures

Tables

PREFACE

Music, Technology, and Education has become an established field of study at the intersection of three distinct disciplines relating to artistic practice. Educators are aware that some learners actively engage with technology in both formal and informal music settings and how this can be a powerful catalyst for music-making. From a scientific perspective the area draws heavily upon engineering, computer science, and physics for the theoretical and practical application of many of the hardware- and software-based tools used in artistic creation. Perhaps it is within the world of music that the effects of digital technology have had some of the most profound effects on both music consumption and creation. Although it is not the intention of this volume to discuss how digital technology has affected the music industry, it is prudent to be aware of how music is being consumed through mostly lossy and some lossless digital file formats. A change in how we access, listen, and ultimately value music has all been brought into question since the increase in availability of digital technology relating to the art. Perhaps of a similar importance for the educator is the democratisation of technology and how this relates to how learners can actively engage with musical creation with technology, once only possible in the commercial world.

This companion has been developed to define, update, and draw together a burgeoning area of pedagogical research in music education that uses technology as a general underpinning. The focus has shifted in recent decades from a (sometimes) procedural investigation of the use of technology in music education to a more thorough examination of the theoretical aspects of the domain driven by evaluation and investigation. Therefore, a major volume that is the focus for this research is not only timely but also necessary.

Technology is now broadly accepted as a general underpinning to music from both an education perspective and general musicianship perspective. Whether composing, performing, or researching music, technology has become a valuable tool in the development of musical skills. This volume will consider the major aspects of the use of technology in music education and is divided into four parts:

- Contexts
- Real worlds

- Virtual worlds
- Developing and supporting musicianship.

Part I is intended to provide a platform for the rest of the volume and begins by examining the historical and philosophical contexts of technology in music. It also addresses topics such as special education needs (SEN), cognition, experimentation, and audience engagement alongside issues such as gender and a broad review of information and communications technology (ICT) in music education. Part II establishes several real-world scenarios that relate to music, technology, and education such as computers, composition, performance, production, and the curriculum. Part III explores the virtual world of learning through our understanding of media, virtual learning, video games, and online collaboration. Part IV highlights the framework for providing support and development for teachers, using technology to understand and develop musical understanding (aural training, harmony, synthesis, etc.), as well as examining sonic heritage and setting up signposts for future research. Each part is preceded by an editorial that draws together and highlights themes contained in their respective chapters.

NOTES ON CONTRIBUTORS

Samuel Aaron is a researcher, software architect, and computational thinker with a deep fascination surrounding the notion of programming as a form of communication. His research focuses on the design of novel domain-specific languages to explore liveness, conceptual efficiency, and performance within programming languages. He works as a Research Associate at the University of Cambridge Computer Laboratory, where he has created Sonic Pi, a powerful live-coding environment for real-time sound synthesis targeted for education. Sonic Pi has been used successfully to teach programming and music within schools but also to live code music for people to dance in nightclubs.

Victoria Armstrong is Senior Lecturer and Director of Education and Social Science at St. Mary's University, London. A sociologist, her research focuses on gender, educational inclusion, and adolescents' music practices, and she is the author of *Technology and the Gendering of Music Education* (2011). She is currently working on a book titled *Women's Musical Lives* which explores the gendered dimensions of women freelance musicians' work. She recently held a Visiting Research Fellowship at Örebro University, Sweden, and serves on the editorial board of *Music Education Research*.

William I. Bauer is Associate Professor of Music Education and Director of the Online Master of Music in Music Education program in the School of Music of the University of Florida. From 2001 to 2013 he was the Director of Music Education and Associate Professor of Music at Case Western Reserve University (CWRU), Cleveland, Ohio. He also served as the University Director of Teacher Licensure at CWRU from 2004 to 2007. His book, *Music Learning Today: Digital Pedagogy for Creating, Performing, and Responding to Music*, was published in 2014.

Adam Patrick Bell is Assistant Professor of Music Technology and Music Education in the John J. Cali School of Music at Montclair State University, New Jersey. He is writing a book about DIY music-making and home recording practices (under contract with Oxford University Press) and plays drums in the New York–based band DFONTE.

Alan F. Blackwell is Professor of Interdisciplinary Design at the University of Cambridge Computer Laboratory. His music research interests include digital notation, new interactive technologies, and timbre perception. He is Co-founder and Director of the Crucible Network for Research in Interdisciplinary Design, through which he engages in technology policy, education, and critical technical practice.

Federica Bressan is Post-doctoral Researcher at the Centro di Sonologia Computazionale (CSC), Department of Information Engineering of the University of Padova, Italy. Her research interests include cultural heritage preservation, interactive multimedia installations, multimodal learning environments, and software applications for children with special educational needs.

Andrew Brown is Professor of Digital Arts and Head of Music Technology at Queensland Conservatorium in Australia. He studied classical and jazz piano at The University of Melbourne and worked as a keyboard player in touring bands throughout the 1980s. During this time an interest in electronic keyboards grew into a passion for music technology more broadly. This passion has fuelled an academic career in teaching and research at The University of Melbourne, Queensland University of Technology, the Australasian CRC for Interaction Design, and now Griffith University. His current performance practice is live coding and he is involved in a range of digital arts practices.

Andrew Burn is Professor of English, Media and Drama at UCL Institute of Education, and Director of the DARE Centre (Digital | Arts | Research | Education), a research collaboration with the British Film Institute. He is interested in the adaptation of theories of multimodality to describe and analyse media texts, and in how such theories relate to the cultural studies research tradition. He has previously taught English, drama, and media studies in comprehensive schools for over 20 years. He was Head of English and an Assistant Principal at his last school, Parkside Community College in Cambridge.

Pamela Burnard is Professor of Arts, Creativities and Education at the University of Cambridge, Faculty of Education. She holds degrees in music performance, music education, education, and philosophy. Her primary research interests include the study of diverse and variegated creativities, the nexus of education, cultural and creative industries, digital learning cultures, and innovative practices, for which she is internationally recognised. She is convenor of the Creativities in Intercultural Arts Network (CIAN), the British Education Research Association Creativities in Education SIG, and Building Interdisciplinary Bridges Across Cultures (BIBAC) International Biennial Conference.

Antonio Camurri is Lecturer at the University of Genova, Italy. His research interests include multimodal interfaces, sound and music computing, computational models of non-verbal expressive gesture, emotion, and social signals; KANSEI Information Processing; and interactive multimodal systems for performing arts and culture, therapy and rehabilitation. Since 2000 he has been the coordinator and local project manager of European projects on ICT, culture, and education (Erasmus IPs), cost action and craft projects. He is the Founder and Scientific Director of InfoMus Lab and of Casa Paganini—InfoMus Research Centre of University of Genova (http://www.casapaganini.org); a member of the ExCom of IEEE CS

Technical Committee on Computer Generated Music; and Associate Editor of the *Journal of New Music Research*. He is the author of over 200 international scientific publications, co-owner of several patents on software systems, and has scientific responsibility for industry contracts at the University of Genova.

Sergio Canazza is Director of Centro Multimediale e di E-Learning di Ateneo (CMELA) at the Department of Information Engineering of the University of Padova, Italy. He is responsible for the course 'Fundamentals of Computer Science' and lecturer for the course 'Sound and Music Computing.' His main research interests involve expressive information processing, auditory displays, and audio document preservation and restoration. He is Advisory Editor of the *Journal of New Music Research*. He has been general chairman and member of technical committees at several conferences and project manager for European projects.

Corrado Canepa is a designer in electronics and multimedia systems as a musician and composer. Over 30 years his work includes the field of communication through sound, in every application, from time to time involving music, electronics, computers, video, entertainment, and education. Four of his electro-acoustic works, created in the studio where he has worked since the 1970s with equipment largely built by himself, have won awards in international competitions of composition. He believes in the necessity of a humanism of technology. With InfoMus Lab (University of Genova), which he co-founded in 1984, he has renewed his scientific-technical and artistic collaboration, sharing the setting of research and experimentation in the service of creativity and expressiveness.

David Carabias is a Lecturer at the Faculty of Education Maria Zambrano in Segovia and his teaching focuses on initial music teacher training and music technologies. As a composer of music for cinema and television productions, he has been responsible for the corporate music image of domestic and international television channels such as TVE, Canal+, Al-Qataria or Romantica and the sound for major exhibitions including *Da Vinci*, *El Genio*, *Alejandro Magno*, and *Encuentro con Oriente*.

Vicky Charisi is a Researcher at the Institute of Education, University College London, and at the Human Media Interaction group at University of Twente, Netherlands. UK. Her research focuses on children's musical behaviours and the development of their musical strategies when they make music within digital environments. She is particularly interested in the investigation of young children's musical thinking and their interactions with innovative user interfaces for music-making. Her research lies at the intersection of the fields of education, music psychology, and music cognition.

Michael Clarke is Professor and Dean of the Graduate School at the University of Huddersfield. His research includes composition, software development for music, and music analysis. His compositions and software have won national and international prizes, including European Academic Software Awards on a record three occasions. He has recently been principal investigator on the AHRC-funded project 'Technology and Creativity in Electroacoustic Music' (TaCEM), working together with Peter Manning (Durham) and Frédéric Dufeu (Huddersfield). This project (2012–2015) builds on Michael's earlier innovative work using software to develop an interactive aural approach to music analysis. In 2011 he was awarded a National Teaching Fellowship.

Paolo Coletta is an IT consultant and a member of the InfoMus Lab staff. He was Research Associate at the National Research Council of Italy, and as a software engineer he contributed to the development and engineering of the software platforms developed at InfoMus Lab, in particular the EyesWeb XMI open software platform. He managed the development of real-time interactive multimedia systems employed in many public events and installations.

Teresa Dillon is an artist, sound director and researcher whose work explores the influence of technological systems and governance on our personal relationships and urban societies. Since 2005 she has addressed these topics through the creation of site-based sound interventions and gallery performances. In 2013 Teresa begin curating Urban Knights, a programme of events that provokes and promotes practical approaches to urban governance and city living. Her work has been exhibited internationally and she has published on music, education, collaboration, and creativity.

Paul Draper is Professor of Artistic Research at the Queensland Conservatorium, Griffith University, where he has held the university chair in digital arts and served as Conservatorium Research Dean. With a 25-year track record as a professional musician and record producer, Paul designed and realised the Conservatorium's recording studios and computer laboratories and networked audio-visual environments. He has developed and led undergraduate and post-graduate degree programs and is the recipient of numerous grants and awards in these areas. Paul is a jazz musician, composer, and record producer who publishes widely on practice-based research, Web 2.0 culture, and record production.

Franziska Florack is Researcher at the University of Bradford. Her work focuses on the use of films in primary school classrooms and their impact on motivation and attainment in Bradford, UNESCO's first City of Film. For her master's at the University of Cambridge, Franzi researched teachers' use of moving images in the secondary school classroom. She has worked as a secondary and further education teacher in the past and now lectures on the BA Film and MA Photography at the new Bradford Film School.

Marina Gall has been Senior Lecturer at the University of Bristol since 1999. Previously, she taught Music and Performing Arts at both the primary and secondary level for 16 years. In her current position she coordinates the one-year teacher training programme for secondary school music teachers. Marina is a co-opted board member and the national coordinator (England) for the European Association for Music in Schools. She co-edited the EAS publication *European Perspectives on Music Education: New Media in the Classroom* (2012), which details the role of music technology in education in 14 European countries.

Andrea Giráldez is an international arts and education coach and consultant and has been a full-time Senior Lecturer at the Faculty of Education Maria Zambrano (Valladolid University) for more than 20 years. Her research and teaching focus on arts education in Ibero-American countries and arts and technology. She has published research and professional articles in a wide variety of publications and is author, co-author, and editor of more than 50 music education books.

Jennie Henley is Area Leader for Music Education at The Royal College of Music in the UK. Her professional career has involved teaching music in many different contexts, including in school, out of school, and in adult community settings. Her research interests surround the development of musicianship in adulthood, including music in criminal justice and the musical development of primary generalist teachers. She has an interest in the intersection between music education and community music, and in developing methodologies for practitioner research and practice as research within both areas.

Martha Hilley is Professor of Group Piano Pedagogy and Director of Undergraduate Studies at the University of Texas at Austin. She has been an active participant in workshops, conferences, and seminars on the international, national, state, and local levels. She has presented throughout the United States and in Italy, Belgium, Norway, Australia, Taiwan, and Brazil, and in the summer of 2016 in Scotland. Professor Hilley is co-author of two college piano texts: *Piano for the Developing Musician* and *Piano for Pleasure*. The texts were the first to embrace digital sequencer technology through discs furnished to teachers as well as the first to provide web-based computer tutorials, downloadable PDF and MP3 files, and dedicated websites for each text (http://www.pdmpiano.org and http://www.pfppiano.org).

Evangelos Himonides is Reader in Technology, Education and Music at University College London, where he currently leads the post-graduate program in music education and supervises a number of doctoral and post-doctoral researchers. He held the University of London's first-ever lectureship in music technology education. He edits the Society for Education and Music Psychology Research (sempre) conference series, is Associate Editor of the *Journal of Music, Technology & Education* (JMTE), Associate Editor of *Logopedics Phoniatrics Vocology*, and Associate Editor of *Frontiers in Psychology*. He has developed the free online technologies for Sounds of Intent (http://soundsofintent.org and http://eysoi.org). He is a Chartered Fellow (FBCS CITP) of the British Computer Society.

Simon Holland is Senior Lecturer in Computing and Director of the Music Computing Lab at the Open University. His research interests are in human–computer interaction, pervasive and tangible computing, and music computing. He also has interests in technology-enhanced learning and is the co-investigator on the E-Sense project and the Older People and Technological Inclusion ESRC seminar series. He has devised numerous human-centred computing innovations such as Harmony Space, the Haptic Drum Kit, the Audio GPS, and Direct Combination.

David Howard is Professor and Head of the Department of Electronic Engineering at Royal Holloway, University of London. He was previously Head of the Department of Electronics at the University of York, where he also led the Audio Laboratory and was a Founder Member of the York Centre for Singing Science. He researches in speech, singing, and music, including their analysis, synthesis, production, and perception, and teaches aspects of music technology. Key research areas include the perception of speech and singing; intonation in unaccompanied singing; the acoustics of singing voice development; and computers and iPads in voice training, performance, and natural voice synthesis. David presented on the BBC4 TV programs *Castrato* and *Voice*, and he presents his work regularly at National Science and Engineering weeks, Café Scientifiques, and the public.

Andrew King is Head of Music at The University of Hull. Between 2009 and 2013 he was the Deputy Dean and then Associate Principal of the Scarborough Campus of The University of Hull. He is Editor of the *Journal of Music, Technology & Education*, and his research areas include the pedagogical approach to sound recording practice and the influence of technology on sound recording practice. He has served on review panels for international conferences in music education and computer music. He has acted as a principal investigator on several grant-funded research projects including the *Connect: Resound* study and the *Remote Music Education Network*. He is also a member of the Audio Engineering Society Education Committee.

Nathan B. Kruse is Associate Professor of Music Education and Coordinator of Graduate Studies in Music Education at Case Western Reserve University, Cleveland, Ohio. He teaches courses in research methods, music cognition and learning, vernacular music, and classroom guitar. His research interests include adult music education, ethnographic traditions of community music, and school–university partnerships.

Leigh Landy is Professor and Director of the Music, Technology and Innovation Centre at De Montfort University (Leicester, UK). He is a specialist in the field of electroacoustic music studies. As a composer one of his aims is to make innovative music accessible to a broad audience. Similarly, many of his projects and publications (seven books, over 100 articles and chapters) focus on making electroacoustic music accessible to young people and interested parties of all ages. He is editor of *Organised Sound*, Co-founder Director of the Electroacoustic Music Studies Network and Director of the EARS and EARS 2 projects.

Marc Leman is Methusalem Research Professor in Systematic Musicology and Director of IPEM, the research centre of the Musicology Department at Ghent University. His lab is an international meeting place for researchers working on expressive interactions with music, using embodiment, and action theory as a point of departure. In 2014 he was holder of the Franqui chair at the Université de Mons. In 2015 he became Laureate of the FWO (Flemish Fund for Scientific Research) Excellence Award Ernest-John Solvay for Language, Culture, and Social Sciences.

Samuel Leong is Professor and Deputy Director (Academic Programmes and Educational Innovation) of the Hong Kong Academy of Performing Arts. He has led a multifarious, interdisciplinary, and international career over the past 30 years spanning education, performance, health, media, technology, business, and administration. He is active as a researcher and his recent research projects focus on Chinese creativity, evidence-based student learning, multi-sensory arts learning, and innovative digitally enhanced pedagogy for the performing arts. He has served as Director of the UNESCO Observatory for Research in Local Cultures and Creativity in Education and Director of Research for the International Drama/Theatre Education Association, and is Adjunct Professor of Interdisciplinary Arts at the Hong Kong Institute of Education.

Al McNichol is Senior Lecturer at Backstage Academy in the UK. He specialises in music production, technology, education, and business with 12 years of academic experience teaching in various UK universities. His research interests include investigating the creative use of digital technology for composition within music education.

Bradley Merrick is Director of Research in Learning and the Barker Institute at Barker College, where he teaches secondary music and oversees research projects and professional learning. He has written several music textbooks for secondary students and specialises in the use of new technology in music education, having presented nationally and internationally in this field, and recently contributed to *The Oxford Handbook of Music Education*. His research interests include classroom-teaching practice and emerging pedagogies, combined with the investigation of new technologies and their use amongst students. He has a particular interest in student motivation and self-regulation, combined with different learning styles and their influence upon understanding. He is the current National President of The Australian Society for Music Education.

Hiromichi Mito is a Professor of Music Education in the Faculty of Education at the Meijigakuin University, Japan, where he teaches research methodology and piano pedagogy. An ISME member since 1995, Hiromichi was a commissioner for the Research Commission (2004–2010) and board member (2010–2012). Hiromichi is a member of the editorial board of the *Japanese Journal of Music Education Research*. His research into informal musical learning has been supported by nationally competitive grants.

Jordan Mroziak is Coordinator of Student Services and Adjunct Professor of Music at Duquesne University in Pittsburgh, Pennsylvania. He is currently pursuing an EdD in Instructional Technology with an emphasis on popular music pedagogy, aesthetic education, and critical and informal pedagogy. His research focuses on creative pedagogy with technology, popular music, the TPACK and SAMR models, maker education, and aesthetic education. Other work includes his participation in Arts Educator 2.0, a professional development project that worked to aid art teachers in the K–12 field with their usage of technology in the classroom.

Luc Nijs is Post-doctoral Researcher at IPEM and a guest lecturer in Music Educational Technology at the Royal Conservatory The Hague (NL) and Luca School of Arts Leuven (BE). His research integrates theory development, empirical studies and practice, focusing on the musician–instrument relationship, the role of body movement in the instrumental learning processes, and the role of technology in provoking an embodied approach to instrumental music education.

Adam Ockelford is Professor of Music and Director of the Applied Music Research Centre at the University of Roehampton in London. He is particularly interested in how the mind makes sense of music without the need for formal instruction. He has worked extensively in the field of learning difficulties and autism, and in the early years. His theories, and their practical applications, are set out in his new book *Comparing Notes: How We Make Sense of Music*.

Jared O'Leary is a musician and researcher whose work focuses on exploring the nexus of music, technology, computer science, video games, participatory culture, and more. Visit JaredOLeary.com to stay up to date with his latest research and connect on various networks.

Tae Hong Park is Associate Professor of Music Technology and Director of the Composition program at New York University. His current interests are in composition and research in multi-dimensional aspects of timbre, soundscape studies, and Digital Signal Processing (DSP). His music has been heard internationally including in Australia, Brazil, Canada, China, France, Germany, Holland, Hungary, Ireland, Italy, Mexico, Slovenia, South Korea, Sweden, the UK, and the United States. He chaired and organised the 2006 International Computer Music Conference (ICMC), and served two terms as President of the International Computer Music Association (ICMA).

Lesley-Anne Pearson is the Course Director for the secondary Initial Teacher Education ITE PGCE course at the University of Huddersfield in the School of Education and Professional Development. Her main research interests are the challenge for teachers following pupil transition from KS2 into KS3, Music and the Deaf, and Formative Assessment processes and procedures.

Carrie Anne Philbin is Director of Education at the Raspberry Pi Foundation and an award-winning computing teacher and author of *Adventures in Raspberry Pi*, a physical computing book for teenagers wanting to get started with Raspberry Pi, programming, and digital making. She is also the creator of a YouTube series for teenage girls called 'Geek Gurl Diaries.' Episodes include interviews with women working in technology and hands-on computer science–based tutorials. Carrie Anne is Chair of the Computing at Schools diversity and inclusion initiative 'CAS #Include,' a CAS board member, and a director of the Python Software Foundation.

Clint Randles is Associate Professor of Music Education at the University of South Florida School of Music and recipient of the 2015 Michael L. Mark Music Research Award for outstanding research by an early career scholar/researcher, issued by the University of Michigan. His research interests include the intersection of motivation theory and creativity, and exploration of the construct *creative identity*.

Eric Rosenbaum is PhD graduate of the MIT Media Lab. His academic work explores the intersection of music, play, and improvisation. He has a background in neuroscience, music, and education and has developed a number of music apps. He now works for the Scratch team in the Lifelong Kindergarten Group at the MIT Media Lab.

S. Alex Ruthmann is Associate Professor of Music Education and Music Technology in the Steinhardt school at New York University. Ruthmann served as President of the Association for Technology in Music Instruction, is currently, Associate Editor of the *Journal of Music, Technology, & Education*, and has served as Chair of the Creativity special research interest group of the Society for Research in Music Education.

Matthew Sansom is Senior Lecturer and Creative Music Technology programme director at the University of Surrey. As an artist Matthew works across a variety of media and contexts including sound, video, sculpture, installation, performance, and musical composition. He has exhibited and performed internationally and has received commissions from the Four Seasons Hotels Ltd., Liverpool City Council, and the Huddersfield Contemporary Music Festival.

Jonathan Savage is a Reader in Education at the Institute of Education, Manchester Metropolitan University. He is a Deputy Director of the CREATE research group within ESRI.

Jonathan is widely published in a range of areas, including using technology in education, supporting gifted/talented students, the arts, creativity, assessment, and cross-curricular approaches to teaching and learning. He works as a series editor for Routledge.

Kyle P. Snyder is a Professor within the Ohio University School of Media Arts & Studies, where he is also Assistant Director of Ohio University's High School Media Workshop. His research interests include pedagogical approaches relevant to the field of audio engineering and specifically how audio students best learn. He is co-chair of the membership committee and vice-chair of the education committee for the Audio Engineering Society.

Cynthia Stephens-Himonides is a freelance piano teacher and Research and Evaluation Consultant for Kuumba Youth Network in London. Her research interests include music education and more specifically group piano pedagogy. Prior to her work in the UK, she was a university teacher-educator and group piano specialist in the United States and former chair of the Research Committee of the National Conference on Keyboard Pedagogy. She also served as a Foreign Expert in China in group keyboard teaching and Research Associate at the UCL Institute of Education in London.

Evan S. Tobias is Assistant Professor of Music Education at Arizona State University (ASU), where he teaches both undergraduate and graduate courses and heads the Consortium for Innovation and Transformation in Music Education (CITME) (formerly the Consortium for Digital, Popular, and Participatory Culture in Music Education [CDPPCME]), which he founded in 2009. He is also a member of the ASU Music Education Research Group. His research focuses on creative uses of digital media and technology, issues of social justice, expanding beyond traditional music curricula, and approaches to integrating popular culture and music in music classrooms.

Kari Veblen is Professor of Music Education at the University of Western Ontario, London, Ontario, Canada, where she teaches undergraduate and graduate courses. Current research interests include community music networks f2f and online, lifespan music learning, Irish/Celtic traditional transmission, and vernacular genres. Thus far, Veblen has written over 70 peer-reviewed works and presented over 260 invited lectures and conference presentations worldwide. Her fourth book is *Community Music Today* (with Messenger, Silverman, and Elliott). Veblen is Co-founder and Associate Editor of the *International Journal of Community Music.*

Gualtiero Volpe is Associate Professor at the University of Genova. His research interests include affective human–machine interaction, modelling and real-time analysis of expressive content, multimodal interactive systems, and analysis of social interaction. He was Chairman of the V International Gesture Workshop and of the 8th International Conference on New Interfaces for Musical Expression (NIME 2008). He was guest editor of special issues for *Journal of New Music Research*, *Journal on Multimodal User Interfaces*, and *Entertainment Computing*. He participated in several international (EU FP5, FP6, FP7, H2020) research projects. He was President of AIMI (Italian Association for Musical Informatics) from 2010 to 2014. He is co-author of more than 100 scientific publications.

Angela Voyajolu is a qualified music therapist and specialises in work with children in the early years. She is currently pursuing a PhD at the University of Roehampton's School of Education in London on young children's musical development, and has worked on the Sounds of Intent project for a number of years as a research assistant.

Janice Waldron is an Associate Professor of Music Education at the University of Windsor, where she teaches Music Education and Ethnomusicology courses. Her research interests include informal music learning practices; online music communities; cyber ethnographic research methods; Irish, Old Time, and bluegrass traditional musics; lifelong learning; and adult music education. She is on the editorial board of the *Journal of Music, Technology, & Education*, and serves as a reviewer for *Music Education Research*.

Ge Wang is Assistant Professor at Stanford University's Center for Computer Research in Music and Acoustics (CCRMA), and the Co-founder of Smule (reaching over 125 million users). He researches areas including interactive design and software for computer music, mobile and social music, laptop orchestras, and education at the intersection of computer science and music. He is the inventor of the ChucK music programming language and the founding director of the Stanford Laptop Orchestra (SLOrk) and Stanford Mobile Phone Orchestra (MoPhO). He is also the designer of the iPhone's Ocarina and Magic Piano.

Serena Zanolla is a special educational needs teacher in a primary school at Gorizia Educational Institution, Italy. She has the task of supporting school children with learning difficulties and/or disabilities in order to optimise their potential within a variety of educational settings. Her main interest is to design teaching methods that respond to individual differences and benefit all children. In particular, she is interested in implementing innovative instructional paths exploiting the motor component of learning. She believes that the present technology can help to achieve this goal and that the Interactive and Multimodal Environments in physical spaces are a good place to start.

PART I

Contexts

This companion begins with a philosophical view of technology, culture and the arts in education. It is important to pause and consider not only the impact of digital technology upon music but also the arts and education more generally. Andrew Burn provides a fascinating perspective of this phenomenon and insightful views on how deeply rooted technological change is within culture. Several consequences are drawn out of this discussion that highlight the neophilism of some work in this area, the new opportunities that digital technology can present, the need to avoid a division between material technologies and conceptual learning, and the elevation of technology beyond the instrumental through the craft, tools, knowledge and aesthetic shaping that also locates technology from a social and cultural perspective. This chapter serves to not only begin this section but also to provide a foundation for the entire volume.

The second chapter examines in more depth what we consider to be instrument technology. Tae Hong Park provides a historical context and brief overview of instrument technologies, highlighting philosophies, aesthetics and trends. Attention is drawn to how instrument-building technology has found a place within educational institutions, as well as insightful comments concerning the potential future development of instrument technology in education. It would seem that just as the democratisation of technology has afforded opportunities for music making beyond an enclosed industry, this can also be profoundly felt within the design of new instruments and open up new possibilities of collaboration beyond the learners' immediate environment. Leman and Nijs offer a view of cognition and technology for instrumental music learning and an architecture to enable this. This work is particularly concerned with interactive and assistive forms of technology within educational technologies and instrument learning, highlighting the need to design music instruments that consider the time-critical and fine-motoric schemes from a human interaction viewpoint. Attention is also drawn to the need for further empirical evaluation in this area.

New instrument technologies emerge and ways of creating music through the use of technology. Whilst earlier electronic technologies created unique instruments such as the *theremin*, other forms of digital synthesisers merely attempted to emulate existing instruments, although many had the ability to create unique sounds. Live coding is an emergent field of artistic endeavour and this is discussed in chapter 15 of Part II by Ge Wang, one of the leading innovators of the laptop orchestra. Chapter 4 provides a foundation for that work in that it gives a perspective of learning from live coding. Within these pages Burnard et al. highlight the current position in teacher education, the lack of confidence for teachers in this area, and how educators could be empowered to take risks and provide opportunities between coding and musical practice with digital technology. Part of the basis for this discussion is provided by the revolutionary Sonic Pi project that the authors developed and evaluated.

The next chapter, 'The Sounds of Music' follows on from live coding by also highlighting the need within the general music curriculum for more experimental forms of music making. Leigh Landy discusses the highly successful *EARS 2* project, which is a powerful enabler for learners to compose music with sounds with a focus away from the notational aspects of music. The chapter discusses the importance of aural awareness and making music education by making engagement possible from a relatively low threshold of prerequisite skills and musical knowledge. Landy also acknowledges the importance of 'the music of notes' within culture but typically is a flag bearer for new forms of musical expression. Teresa Dillon likewise makes the case for sound exploration through sound art practice and why it should be included within a music curriculum. This is approached from a unique viewpoint by drawing upon the work of two contemporary sound artists. It builds upon the previous chapter by Landy, who discusses a pedagogical platform for learners engaging with sound art; Dillon gives an urban dimension to practitioners working in the field.

The next chapter provides a sobering reminder to educators that the enthusiasm with which technology is met in some classrooms can have repercussions from a gendered perspective. Victoria Armstrong is author of the acclaimed *Technology and the Gendering of Music Education*, and through this chapter she discusses how the uptake of post-16 level courses in music technology is largely by males, and provides a focus for the gendered aspects of digitally mediated music education approaches. Armstrong draws upon feminist science and technological studies as well as gender-technology relationships, and argues from a gender perspective that through technology a more exclusive curriculum is created, and from an engagement perspective this has consequences educators need to carefully consider. We then continue to a theoretical framework for musical development in early years provided by the well-established collaborative project Sounds of Intent. What is also of great importance here is the original ethos of the approach that was aimed towards special educational needs (SEN) and the opportunities that can be discovered. This chapter views this project from a technological perspective and the fostering of critical thinking and placing it as the centre of the focus rather than a tool.

The final chapter in this part provides a nexus to Part II on *real-world* scenarios. Bauer and Mito provide an overview of information and communication technologies (ICT) in Music Education in the United States and Japan. The authors describe a variety of ways that technology is being used to facilitate music learning and musical participation in general, examining the ICT knowledge and skills needed by music teachers to effectively integrate technology into diverse student learning experiences. It provides a useful context for what follows in Part II, which explores particular aspects of technology in music education that follow on from the theoretical framework provided by this opening part.

1
DIGITAL ALETHEIA
Technology, Culture and the Arts in Education

Andrew Burn

Oh I am a handweaver to my trade
And I fell in love with a Factory maid
And if I could but her favour win
I'd sit beside her and weave by steam.

The Handweaver and the Factory Maid (Trad.)

This piece of history may seem a long way from the digital revolution and the classroom. It may reveal, however, some telling questions about the relation between technology and society which, with a little teasing out, we can apply to the question of how education shapes and is shaped by technology, and what this means for educators in the arts in particular.

The song tells of the disastrous effects of mass mechanical weaving on the cottage industry of handloom weavers in the late 18th and early 19th centuries. It split communities, drove country-dwellers into towns and stripped out much of the craft of weaving. It deprived workers of ownership of the means of production and exemplified the dire consequences of mass industry for working people and their landscape, a chapter in a narrative elaborated by critics of the social consequences of the Industrial Revolution, from Blake to Dickens. This narrative persists into the media age, as we know. In Adorno's version, the mass industry of popular music is used to blunt the sensibilities of the people (Adorno, 1941). In Benjamin's influential essay, the mechanization of art proves profoundly ambiguous, apparently destroying the aura of the individual artwork, yet oddly democratising it (Benjamin, 1938). It adroitly constructs the ambiguity of technology and art in the post-industrial world, and this ambiguity characterises debates, research and practice in education today.

The narrative in the digital age has shifted. Critiques of inexorable corporate power over the lives of individuals have given way to an unstable mix of pessimisms and optimisms: postmodernist pessimism about the empty and depthless simulacra seen to constitute contemporary cultural forms; optimistic celebration of the apparent shift of power from media producers to those who used to be thought of as an undifferentiated audience. The latter view can cite in support instances such as the work of video editors who—for the first time able to buy affordable tools such as Final Cut Pro in the early 21st century—could leave their production companies and set up as freelancers working from home. In short, some sectors of the economy gave way again to cottage industries, and the digital descendant of the handloom weaver set up shop. These developments represent a curious mix of small-scale agency and the big corporations' exercise of a hegemonic power, controlling large-scale publishing and distribution (in the games industry, for example), and catering to our creative and communicative needs in return for our content, our submission to advertising and our compromises over privacy.

In the case of education, the celebratory rhetoric is tempting and ever-present. Digital making in school can be seen as another kind of cottage industry, except that it encounters a double disenfranchisement: not only that of working people disenfranchised by mass industry, but also of young people whose creative endeavours were typically disregarded by the adult world as inadequate by adult standards, trapped in an eternal mode of apprenticeship. The celebratory mode can be tempered, then, with due recognition of the limits on what is possible, as I'll suggest later in this chapter. In particular, we have been warned by others of the dangers in simplistic views of the transformative powers of technology in education: the dangers of technological determinism (Selwyn, 2008), critiques of Prensky's (2001) 'digital natives' trope (Jenkins, 2007) and challenges to popular assumptions and academic arguments about gamification (Buckingham, 2007). As my argument unfolds, then, I will look for the kinds of balance which researchers and practitioners might strike.

However, the handweaver and the factory maid prompt other questions pertinent to the question of technology in education. What exactly *is* the value of the craft the handweaver was so skilled in? And by extension, what kinds of craft, skill and artistry do educators in the arts attempt to develop in their students, and what part might digital technologies play here? Some might believe that they threaten the pre-digital skills of hand, eye and ear; some believe they extend, complement and augment them.

Another question is prompted by the history of the song excerpt in the epigraph. Like all folksongs, it exemplifies a mode of oral transmission we might consider to have died out. It became popular in the British folk revival and was performed and recorded by a range of contemporary folk singers and bands, including Martin Carthy with the band Brass Monkey. The sleeve notes say:

> the present song has not yet been found in printed sources. It was collected from a William Oliver of Widnes and partially refurbished by A. L. Lloyd from the "chambermaid original." Martin [Carthy] learned it from the actor Roger Allam.

This narrative raises a number of interesting questions for debates about the arts: the nature of authorship, the transformation over time of cultural texts and the nature of creativity involved at the various stages of composition, revision, collation, collection, transcription and performance.

But, equally significant for this chapter, this cultural object is now digital in a variety of ways. Although I own the Brass Monkey album, the preceding quotation is copied and pasted from a web page. The album itself is now on my iPhone, and my car plays it automatically via Bluetooth. However, these types of text remain editable, fluid, auditory and mobile across different social and cultural contexts. They are examples of the retention of oral sensibilities in the digital age which Walter Ong described as "secondary orality" (Ong, 1982).

All of this reminds us, then, that the relation between the digital arts and education is not only a question of innovation, newness and the future; it is also a question of history, another chapter in the metamorphosis of cultural resources over time, across generations and over successive tools of composition, performance and distribution.

These are some of the questions this chapter will explore, then: What kinds of creative making do the digital arts in education make possible? What are their histories? What constraints and opportunities do they offer? What human endeavours lie behind the gleaming surfaces of new media? How can we relate the material properties of hardware and software to social and cultural purposes, and to the processes of teaching and learning?

I will aim to separate out 'real-world' technologies of the digital arts from 'ed-tech'; consider technology's relation to culture; emphasise the role of technology in practices of creative production and processes of learning; and consider the implications of virtual worlds and bodies for the arts in education.

Real-World Technologies and Ed-tech

'Educational technologies' have their own domain of practice, policy, commerce and research; their own conferences, journals, marketing practices and forms of deployment in classrooms. They are not the focus of this chapter. It is true that there are many areas of overlap between technologies specifically designed for education and those used in the wider society, yet the distinction is important. It can be simply summarised by the difference between learning through a technology and learning with or about a technology, a distinction made by David Buckingham to which I will return.

On the one hand, using an interactive whiteboard in combination with a modern foreign language software package is clearly an instance of 'learning through.' On the other, using Cubase or Adobe Premiere for making music or film is clearly learning with and about. These softwares have not primarily been designed as learning tools: they are for making, just as a chisel, lathe or paintbrush are technologies for making in the pre-digital age—and, significantly, remain with us. To be sure, the use of Cubase, Premiere, chisel, lathe or paintbrush all enable learning: the tools complement the pedagogies of school, home or apprenticeship. But the point is that they are authentic instruments in the wider world, used by creative communities in common.

By contrast, interactive whiteboards, drill-and-skill softwares, virtual learning environments and classroom presentation tools lack cultural authenticity. Despite their novel appeal and digital affordances, they are the descendants of overhead projectors and blackboards. I do not mean to demonise such instruments; they have their place, have always been with us, and require deft use as part of the pedagogic toolkit. We may see them, perhaps, in terms of what Heidegger, in his influential essay on the question of technology, referred to as "the instrumental and anthropological definition of technology" (Heidegger, 1954/1977, p. 287). Heidegger's move beyond this is to amplify the Greek conception of *techne*, relating the sense of craft and skill to society, knowledge and truth, an amplification I will consider in the next section. In the same way, we can argue that the technologies of presentation in the classroom—the '*contrivances*', to use Heidegger's word—of the pedagogic toolkit—are less important than the real-world technologies of artist or scientist. These present the real value of the digital revolution: that it pulls education into the world of digital culture, and puts into the hands of teachers and children the same tools that professional artists, craftspeople and engineers use. The implications of this are profound: the potential inversion of the usual relation between producer and audience; the productive erosion of adult–child hierarchies; a wholesale revision of the agency of children and young people in the arts; and the quality and value of their work.

I have indicated the need to balance celebratory accounts of digital media and learning with cautionary notes, and one is required here. While the digital era provides transformative possibilities in education as in society at large, it does not provide magic solutions. A student faced with video editing software, a game design program or a music editing tool may well be overwhelmed by its complexity. We cannot assume that this student is somehow magically equipped with native digital skills, or able to transfer his or her uses of Facebook, texting or online gaming into specialised design tools. Time and time again, the research reminds us of the importance of pedagogy: the skill of the teacher in building on young people's experiences of digital culture, building bridges from the tools they are familiar with to those they have not encountered, and plugging the various versions of the digital divide that still bedevil all societies to some degree.

Technology, Society and Culture

Heidegger's account of *techne* makes a bold set of connections. His first move is to relate the traditional notion of *techne* as craft to the notion of *episteme*, or knowledge. Technology is not just about tools; the tools require knowledge to be used effectively and, as we shall see later, the tools can shape the knowledge just as the knowledge can shape the tools. How this might relate to the Vygotskian conception of tools in the service of learning is considered in the following section. Heidegger's next move is to relate this double structure (*techne* and *episteme)* to the notion of *poiesis*—the antecedent of our word 'poetry'—often translated as 'making'; thus recapturing the connections between craft, artistry and poetry that obtained in ancient Greece. This connection is of evident value to us as arts educators, encouraging us to see aesthetic purpose in the use of technologies; and it has often been invoked by arts educators (e.g. Connolly, 2014; Swanwick, 2001). In my own field of media education, it is sometimes the case that a narrow focus on the tools of filming and editing, along with the rhetorical functions of critical analysis, can obscure the poetics of media-making: attention to aesthetic form and cultural value. If episteme can be seen as a broad critical knowledge and understanding about the role of the arts in society, in short its critical and rhetorical functions, then poiesis might remind us of the related aesthetic functions of art, media and text (Burn, 2009a).

Heidegger has one more move to make, however. He proceeds from this triple synthesis to the notion of *techne* as *aletheia*, or truth:

> But where have we strayed to? We are questioning concerning technology, and we have arrived now at *aletheia*, at revealing. What has the essence of technology to do with revealing? The answer: everything. For every bringing-forth is grounded in revealing. . . . *techne* is the name not only for the activities and skills of the craftsman, but also for the arts of the mind and the fine arts. *Techne* belongs to bringing-forth, to *poiesis*; it is something poietic.
>
> *(Heidegger, 1954/1977, p. 212)*

The implications of this are twofold. First, 'bringing-forth' suggests that whatever truths are constructed in artistic practice do not come from nowhere. In some way, they were already there, in the material substances of the artefacts, or in the disposition of the tools themselves, or in the cultural resources deployed in the making of the artwork. This notion contributes usefully to the vexed debate about 'originality' as a criterion for creativity in education, and arts education particularly—a debate explored in the next section.

This in turn asserts the importance of the physical tools and material media in the arts. A similar argument is made in relation to how the art of visual design creates meaning in Kress and van Leeuwen's *Reading Images* (1996). Their point is that theories of signification—linguistics and semiotics—typically attend to abstract systems of grammar, lexis, signifier and signified rather than to the material media employed by sign-makers. They propose that the material medium, whether paint, stone, paper or pixel, contributes to the meaning made. They refer to this theme as the 'technologies of inscription,' and make a further point relevant to this book: such technologies can be seen across human history in three eras. The first they call technologies of the eye and hand: paintbrush, chisel, pen and so on. The second, from the 19th century, is the era of recording technologies—photography and sound capture, whose ontologies are referential: their offer seems to be to capture or represent the 'real' world. The third, of the digital age, they call synthesising technologies, in that the referential ties are loosened, and they may build meaning-systems out of the material of previous texts. This third argument echoes contemporary images of remix culture, a metaphor rooted in musical practice, and now applied generally to media mash-up practices (Ito, 2008). It also echoes the now-familiar postmodernist proposal of reproduction and the simulacrum, while avoiding its pessimism.

The general significance of all this for the digital era in education is, as I suggested earlier, a transfer of agency from the producers of text and artwork in the professional, industrial and commercial spheres to the vast bulk of the population previously thought of in media theory as the audience. This shift from the mass deployment of technology in the interests of institutional power and capital in the industrial age has given way to a kind of democratisation of the tools of making. As educators, we are in the happy position of being able to deploy such tools with our students.

In the world of academic cultural studies, this kind of optimism increasingly characterised studies of youth culture during the 1980s and '90s. It was justifiable in many ways, but inevitably led to a critique of what McGuigan called "cultural populism" (McGuigan, 1992). The object of study here was more broadly concerned with young people's agency in engaging with popular culture than specifically with digital tools, but the same celebratory tone persists in accounts of young people's digital culture (Prensky, 2001; Tapscott, 1998).

A middle ground was needed; and one such argument is proposed by David Buckingham in *Beyond Technology* (2009), a sharp critique of the excessive claims of digital technologies to transform education. Buckingham is excited by the potential "for students to take control of the 'means of production,'" but dismayed that "so many uses of technology in education seem to me to be unimaginative, functional and misguided." He concludes that "we need to be teaching *about* technologies, not just *with* or *through* them" (Buckingham, 2009, p. viii).

Buckingham's positive angle, that digital media can enable students to take control of the means of production, echoes the popular Marxist aspiration, of course; and in general terms captures the points made earlier about a shift of power from the producers of (in this case) media, music or artworks more generally to the former consumers. A caveat made by John Fiske in his account of popular culture and the media (1989) is that while people may make their own media and meanings, they do not always do so with materials of their own choosing (an adaptation of another famous Marxist dictum). We can consider how this applies to the arguments rehearsed earlier: to Kress and van Leeuwen's argument about the semiotic provenance of the material media we employ; to Ito's discussions of remix and mashup cultures; and to my own accounts of young people's unstitching of digital film to make their own texts (Burn and Durran, 2006). In concrete terms, to digitally remix cultural resources, whether through the layering of Photoshop, the stratified timelines of Premiere or the track-mixing of GarageBand, is to create new texts, but also to be constrained by the generic and specific patterns of the source material. Is this a newly depthless simulacrum, as postmodernism would have it? Or is it simply the digital version of the constraints which artists have always made the most of, from Michelangelo's imposition of Greek statuary onto the tropes of late mediaeval Christian iconography to Joyce's reworking of the *Odyssey*? We must all choose our view; mine inclines to the latter.

Buckingham's dismay is provoked by the unimaginative, functional use of digital media in education. This may be teased into three categories, under further inspection. One quite general category might be the instrumentalist notion of technology I discussed earlier, associated with Heidegger's notion of technology as contrivance, an *instrumentum* (1954/1977, p. 290). A second might be what we could call the bureaucratic use of professional technologies—literally, in the case of Microsoft Office. While my argument here is for the creative use of mainstream creative technologies in the arts, on the basis of a parity between adult artist and child artist, to import a digital version of an office imposes serious constraints upon the kind of adult world into which we are inducting our students. A third category of 'unimaginative use' might be poor-quality educational software. Buckingham himself has conducted a study of 'edutainment' software, finding generally that it suffers from inauthenticity, at its worst masking regressive pedagogies of drill and skill behind superficial offerings of game and play (Buckingham and Scanlon, 2002).

A final point to amplify in Buckingham's argument is contained in the last sentence, to which I referred earlier: that we should be teaching *about* technologies, not just *with* or *through* them. Buckingham's argument here is relatively straightforward from the point of view of media education. It means that, rather than treating the medium of film, or more recently video game, as a way of teaching history, science or geography, we should teach about these media as cultural forms in their own right. Film and video game can be treated as cultural forms in the curriculum in much the same way as literature, music and drama, and arguably should be. They should not be used as transparent vessels into which curriculum content is poured in the service of dubious claims of transformation.

However, the case is less straightforward if we consider digital tools. What might this mean? What would it mean for media teachers to teach about digital editing softwares, or for music teachers to teach about Sibelius or Pro Tools, or for art teachers to teach about Photoshop? What would it mean to make these technologies objects of study, not just means to an end? In media education, it is certainly the case that teachers and researchers have recognised that the softwares have become a distinctive part of the learning process. They might, for example, carry metaphors of older technologies, such as the 'razor tool' of Adobe Premiere, with its reference to the cutting of celluloid film. They might, by contrast, introduce new ideas distinctive to the digital medium, such as filters, timelines and export formats. In both cases, these concepts and their associated terminologies become part of the metalanguage of the subject in question, sitting alongside other conceptual apparatuses specific to the domain: shot distance, camera angle, narrative; or melody, harmony, rhythm, tempo; or frame, colour, line.

Two further distinctions should be noted. The razor tool in Premiere is specific to the practice of film editing: a historical metaphor, profoundly connected with the users' perceptual engagement with film editing, cutting and shot creation. By contrast, tools to extract and manipulate individual frames have something in common with visual design practices, while tools for the manipulation of the soundtrack, controlling volume, sequence, duration and audio-layering have something in common with audio and music softwares.

Finally, tools like filters, export formats, timelines, copy-and-paste functions and so on are generic across all composition tools. They exemplify what Manovich proposed as five principles of digital media: numerical representation, modularity, automation, variability and transcoding (Manovich, 1998). In practical terms, they mean that we can create texts which pull together different modes and media—images, sound, film, music, spoken language, written text and so on—that we can make provisional combinations of these, view them in real time, then remake them as much as we need to; and that we can transform media content across different modes of representation.

This has wide-ranging implications for the arts, but perhaps the broadest is that we need to attend to the multimodal nature of contemporary culture (Kress and van Leeuwen, 2000). Film and video games are good examples: they synthesise image, action, gesture, speech, sound, music, designed space and so on (Burn, 2013). To effectively analyse them we need to take all the 'grammars' of these design traditions into account. To deploy them with young people in schools, the best way forward is to involve the art teacher, media teacher, English teacher, music teacher and computing teacher—a mix which characterised a recent project of mine in which 11-year-olds made machinima films of their own devising.[1] Figure 1.1 shows two shots from the film depicting a fantasy visit to Cleopatra's palace, the written and spoken language of the script, and the music track composed by the children with the composer-in-residence to signify 'Egyptianness.' This can be seen as 'connected learning' (Sefton-Green, 2013) or as multimodal literacy (Jewitt and Kress, 2003); but it will also involve, if we follow Manovich's argument, paying explicit attention to the softwares that pull these expressive modes together.

The argument here is for a school version of Manovich's more recent proposals for software studies (Manovich, 2008). He makes the case for explicit attention to what he calls the cultural softwares, because they represent remix culture; they enable us to participate in such a culture because we have shaped them to accomplish this function:

> At the first approximation, we can think of these mechanisms as forms of remix. This should not be surprising. In the 1990s, remix has gradually emerged as the

Figure 1.1 Screen shots, script and music from a machinima film made by 11-year-olds.

> dominant aesthetics of the era of globalization, affecting and re-shaping everything from music and cinema to food and fashion. (If Fredric Jameson once referred to post-modernism as "the cultural logic of late capitalism," we can perhaps call remix the cultural logic of global capitalism.) Given remix's cultural dominance, we may also expect to find remix logics in cultural software.
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> *(Manovich, 2008, p. 24)*

We might, then, consider how the arts curriculum can teach about digital media in two senses: first, about digital art forms, such as digital film in all its guises, born-digital music, digital visual design and digital games; second, about how the digital tools for the making of these art forms themselves encode meanings about the knowledge and skills involved, and produce the metaphors of making distinctive to each art form, but also to the multimodal synthesis of modes and media, and the artistic traditions that lie behind them.

Furthermore, we can consider how Manovich's argument is in certain ways an extension of those rehearsed earlier, which suggest how the material medium of tool and artefact contribute to the meanings made. In remix culture, new meanings do not come from nowhere, but are reshaped from inherited cultural resources. We might consider how this could be an example of Heidegger's revelation or 'bringing-forth'—latent meanings are there to be made, earlier utterances contain the seeds of later ones, meaning-making tools are systems of potential meaning, encouraging some kinds of shape and pattern and inhibiting others.

This argument is compelling, but it is useful to recall here the example I began with: 'The Handweaver and the Factory Maid.' This song was already a remix before the radical folklorist A. L. Lloyd remade it with new combinations. The oral tradition is a tradition of patchwork, improvisation, recombination and transformation. 'Bringing-forth' works equally well as a metaphor for the revelation of historic meanings recast anew as it does for the remix practices of contemporary youth culture.

The argument for an attention to tools of making, however, can apply across these histories. The specific question we face as educators is how the argument might relate to learning, which is the subject of the next section.

Mental and Physical Tools: Creativity and Learning

How are learners inducted into the use of technologies for making, representing and communicating? Which kinds of induction happen in the wider society, through peer cultures and families, and which happen in formal sites of learning? What is the status of the learner, and what kinds of learning progression can be mapped? What purpose or end does the learning serve?

In my own field of English, media and drama education (and arts education more broadly), the best way to think about technologies in relation to learning is to apply and adapt the Vygotskian notion of tools, which challenges mental–physical dualism (Vygotsky, 1978). Vygotsky sees tools as both psychological/internal (we can think of language, semiotics, musical notation, algebra and visual grammar) and technical/external (and here, amongst other artefacts, we can think of digital tools). The interdependence of internal and external tools helps us to consider how conceptual development occurs in tandem with the use of tools in the physical world.

Two examples of real-time digital composition might help to concretise this notion. In digital video editing, a learner might 'scrub' through the timeline of a sequence of film she has created. This was not possible in analog editing—the digital representations of the temporal sequence of the film, and the pointer tool allowing the real-time scrub, with the algorithm in the software controlling the media database of digitised video, are particular affordances of the digital medium. At the same time, the user must operate a series of conceptual understandings: the narrative sequence, or rhetorical purpose, of the video being made; the grammatical links being forged, visible on the screen, such as the shot transitions (cut, dissolve, fade, wipe, etc.); and the relation between visual and audio tracks. In Vygotsky's schema, the conceptual tools prompted by the external physical actions become internalised, so that understandings of narrative, sequence, duration, synchronisation and so on are developed and reinforced. Reciprocally, the next time the learner uses the software, these concepts are applied outwards to manipulate the tools and create the desired artefact.

A musical composition software would follow a similar pattern. A learner using a software such as Finale obtains real-time feedback on the notes being dragged onto the staff: on their melodic value, their time value, their harmonic value and their rhythmic value. As in the video editing tool, the dialectic toggling between external use of the tool and internal conceptual understanding, mediated by linguistic terminology, symbolic notation, and midi or sampled sound enacts the interdependence of mental and physical tools.

These two examples exemplify the Vygotskian notion of tools, but they also represent his account of creativity in childhood and adolescence (1931/1988). His view of creativity involves the imaginative adaptation of cultural resources through the use of internal and external tools, subordinated to rational processes of conceptual thought. As in the earlier discussion of remix culture, then, we can have the best of both worlds on the question of originality. The creative work of our students will always engender new artefacts, new representations and new aesthetic patternings which have never existed before; but they will also be built out of the fabric, imagery and soundscape of earlier works by others. They will be, in Bakhtin's term, dialogic, responding to earlier utterances and addressing future ones (1981).

However, two issues remain about the trajectory of learning and the status of the learner, especially in the digital arts. The first concerns the differences there might be between the cultural dispositions of teacher and student towards new media. The deployment of digital tools in popular culture to dream, fantasise, role-play, listen to music, engage with narrative, gossip inconsequentially with friends and engage in subversive and disruptive practices—all these are practices which formal education finds hard to tolerate, preferring to construct more conventional epistemologies and trajectories of civic participation. Yet the function of the arts in society is not to endorse conventional behaviours, rational modes of civic engagement or dutiful vocational trajectories—or at least, not exclusively to do so. The function of the arts has always been also to challenge, articulate alternatives, disrupt, subvert, tell the irrational counter-narrative to the Enlightenment's rational ideal. In this respect, educators do not lack competence with digital tools; but they need to have the courage to build on their students' engagements with popular cultural forms. Many art teachers know that dynamic and creative work must include graffiti art, pavement art, pub signs, cartoon and manga, and video game fan art as well as classical art from the Renaissance to modernism. Many music teachers know that the social energies of rock, pop, reggae, punk and hip-hop, the urban mix of bhangra, the 'nu-folk' indie culture, are as productive of learning as the classical repertoires, not culturally or formally inferior to them. Similarly, the social practices of improvisation, learning by ear and being in a band, can be the real engines of musical learning as much as playing in the school orchestra (Green, 2014). To be sure, all these practices existed before the digital revolution. But they have found, created and exploited new tools in the digital era: informal technologies of tuition, composition, recording, performance and cultural exchange.

Being in a band raises a related issue about learning trajectories. Education invariably inserts learners into a developmental scale, even progressive learning theories such as Vygotsky's zone of proximal development. But all teachers can point to moments when their students' work outstrips their own competence—when the learner can achieve something the teacher cannot. How do we think about the student whose Jimi Hendrix tributes on a Fender Stratocaster leave the teacher open-mouthed? Or the student who creates their own app, sets up a company, and is earning substantial sums while still in the sixth form? Or the student who is a Wikipedia editor at the age of 14? Or the child chorister, a professional musician at the age of 11? These examples may be atypical, but they are by no means rare. They remind us that educators in the arts are constantly managing a daily paradox: that the act of creating for the young people they teach is what the new sociology of childhood refers to as both being and becoming (James, Jenks, and Prout, 1998). It is simultaneously a creative act in the moment, sufficient for and adequate to that moment, and a developmental process. This paradox is intensified by the tools and cultures of the digital age.

Conclusion: Towards Connected Learning in the Digital Arts

The argument I have propounded in this chapter seems to me to produce three clear consequences for the deployment of digital technologies in relation to education and education research.

The first consequence is that digital technologies, despite the neophilism that often characterises discussions of practice, research and policy, are not technologies of rupture. They offer distinctive new opportunities in the plasticity of compositional processes, the remixing of earlier texts and artefacts, the distribution of artworks across space and time, and the conflation of global and local cultures. They invoke new genres, narratives, imagery and social practices in digital culture; they provide new spaces, bodies, tools, fantasies and soundtracks in which we can spin our stories, play our tunes, create affective experiences, and represent our world to ourselves and our communities. Yet all of this has a history. All of it is grounded in pre-digital stories, images and artistic endeavour. The debate about art and the machine runs from the Industrial Revolution to our deliberations about the digital tools of music-, media- and image-making in 21st-century classrooms. Away from the abstractions of cultural theory, we are all aware that the experiments of young people with digital instruments bear some relation to our own early efforts with guitar or violin; that online role-play in World of Warcraft in some way resembles the superhero costumes of our own childhood; that the building of virtual structures in Minecraft has something in common with the sandpits, LEGO and Meccano of earlier generations. Perhaps most importantly, the research tells us repeatedly that the most productive online experiences are those strongly linked to offline life and practice.

The second consequence is the need to avoid, in our understanding of learning, a bifurcation of material technologies and conceptual learning. Vygotsky's insight that the two are intimately connected, that semiotic tools depend on artefacts and events in the material world, and act upon them, helps us to avoid the more crass effects of technological determinism. It helps us to see that it's not (just) the technology, it's the pedagogy and the generative collision of imaginative and rational thinking of the learner that's important—but that these can internalise the properties of material artefacts and develop in responsive complexity through the manipulation of tools.

The third consequence returns us to Heidegger's yoking-together of techne, episteme and poiesis. This synthesis of craft and its tools with knowledge and aesthetic shaping elevates technology beyond the instrumental, as we have seen. It also locates it socially and culturally. The emergence of such a synthesis into aletheia, a 'bringing-forth,' is a sociocultural process. When a child decides that a particular combination of pink and green on an iPad art package will be adequate to represent her father in the composition she is making, the swipe of her finger across pixels on the screen *brings forth* an image in dialogue with her life and earlier representations she's seen in picture book, film and animation. But it also makes something out of the material substance offered in the art package—something very similar to what she might have made with paint and paper, but also qualitatively different to the touch, smell and sight, and capable of different futures and forms of durability and exhibition.

The final consequence has to do with the paradox of learning. It is difficult, but while it is sometimes necessary to work in a developmental mode, where learning occurs in steps, and such steps may be modelled, auto-logged, supported by digital tools, it is also sometimes necessary to acknowledge the value of a composition, production or performance for the moment. These moments may also be made more possible through the communicative functions of online tools, the output formats of composition softwares, the audiovisual capacities of multimodal design packages. These moments may profitably disrupt the inexorable march of learning progression; they may undo the teacher–learner hierarchy, if only temporarily; they may threaten the neat boxes into which the curriculum is shoehorned; they may connect classrooms with global audiences; or they may reveal meanings the curriculum had never intended or foreseen. These may be the kinds of bringing-forth that the arts aspire to, and if the digital arts can make a contribution, then our new classroom cottage industries can have the best of hand and steam.

Note

1. Machinima is animated film made from games or virtual 3D environments. This project, 'Montage, Mash-up, Machinima,' was conducted by the UCL Institute of Education, the University of Leeds and the British Film Institute, and was funded by First Light.

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2
INSTRUMENT TECHNOLOGY
Bones, Tones, Phones, and Beyond

Tae Hong Park

Introduction

Humans have been performing and creating music with instruments for tens of thousands of years, as evidenced by 30,000-year-old flutes[1] made from bones, which serves as one of earliest known examples. Within a very small span of time, humanity has witnessed impressive technological leaps affecting all facets of life, including the way music is performed, disseminated, stored, created, produced, and used in educational contexts. In particular, since uncovering the secrets of electrical energy, the exploitation, control, and mastering laws of electron movement, every facet of music has been dramatically impacted. Rather than using *bones* to build flutes, we now have the ability to electronically generate pure *tones* and combine these sinusoids to create literally any musical timbre imaginable—and even timbres that have been 'unimagined.' Inversely, deconstructing a sound into atomic sonic building blocks is now straightforwardly achieved with any modern computer that can fit into one's pocket. In the area of musical instrument technology, human–computer interaction (HCI) research has developed to a point that one can now use *phones* for playing music. The exploitation of technologies and machines that in the past were housed in huge air-conditioned rooms with expert operators and engineers is now readily available for the masses, enabling sound synthesis, sound recording, sound editing via computers, and playing such sounds via instruments. Technological advances in sound synthesis and microcontrollers have contributed to musical instrument technology development where a musical instrument sound no longer needs to be created by physical acoustic instruments—sounds can be virtually created in real time and transduced from electrical energy to acoustic energy via loudspeakers, where the only moving parts are those loudspeakers. In this chapter, we begin with a brief overview of instrument technologies, its developmental trajectories, philosophies, aesthetics, and trends. We also outline how instrument building technology has found a place in educational institutions and curriculums, especially in the context of hands-on, interdisciplinary HCI-based class settings. The chapter concludes with a summary and thoughts about the future of instrument technology and education.

Brief Overview of Instrument Technologies

Musical instruments can traditionally be divided into four categories: percussion, brass, woodwinds, and strings. These instruments have been around for a long time and each has played an important role in developing the art of music performance and composition. The piano, in particular, is an engineering marvel that has gone through numerous design iterations, beginning as a harpsichord and developing to the piano-forte, employing a hammer-string model to produce sounds with high degree of dynamic sensitivity and wide range of musical expressivity. All acoustic instruments have limited dynamic range, limited pitch range, and limited timbral possibilities. Limitations in sound production, however, are not necessarily negative. Rather, they contribute to what makes a particular instrument idiosyncratic and gives it character. As a matter of fact, limitations make a musical composition itself interesting, as the resulting music created from instruments is as much about the instrument's sonic breadth as it is about the eventual sonic limitations. In short, what makes the trumpet sound unique is its particular dynamic range, pitch range, articulation possibilities, and timbral constraints as a function of time.

As far as dynamic limitations are concerned, the acoustic guitar is probably a well-known, representative example: other instruments such as brass and woodwinds would drown (known as *masking*) a guitarist playing in a typical large jazz band setting. This all changed, however, with the maturing of electrical engineering and its application to the field of musical instruments, its adaptation to sound amplification, eventually leading to the invention of the electric guitar. Around the early 1940s, Les Paul introduced the *Log* (Waksman, 1999)—a 4×4 inch solid block of pine with homemade electronic pickups for amplifying an acoustic guitar. The *Log* largely contributed to the development of the revolutionary standard electric guitar, providing inherently soft-sounding instruments (guitars, in this case) a dynamic boost needed to be on par with other much louder acoustic instruments. The electric guitar, as a matter of fact, revolutionized an entire musical instrument industry and also created a new musical genre commonly referred to as *rock music* (Hunter, 2014). Furthermore, the electric guitar is one of the most beloved instruments today (Lamont, Hargreaves, Marshall, and Tarrant, 2003). Another instrument that exists in both its original acoustic manifestation and its electrical iteration is the (electric) piano. It goes without saying that the piano is also one of the most beloved instruments today (Lamont et al., 2003), and it is perhaps one of the most important ones as well. This is especially a viable argument in the context of Western music traditions, as it can effortlessly take on the role of a solo instrument, an accompaniment instrument, or both, where harmonic, contrapuntal, and melodic ideas can be richly explored and expressed. The electric piano's introduction to the public began in the late 1940s with the electric piano that bears the name of one of the primary inventors (Roads, 1996). This electric piano later became the classic and widely popular *Fender Rhodes*, employing a traditional keyboard interface, metal tines, and pickup for amplifying the sound produced by the tines.

An interesting observation can be made at this point: two of the aforementioned electric instruments are not much different when compared to their acoustic counterparts: for the electric guitar, we have the acoustic guitar, and for the electric piano we have the acoustic piano. The interaction mechanics of the electric and acoustic siblings are fundamentally identical, although differences and nuances do exist as far as performance techniques on either side of the electro-acoustic fence are concerned. What is clear, however, is that these electric instruments were developed to *mimic* the original acoustic instruments in terms of interaction and visual designs. These design strategies, however, slowly began to change with the introduction of digital technology, as we will further elaborate in the next section.

Electronic Instruments and Emergence of Controllers

With the enormous success of the electric guitar and electric piano, a new era of music-making had emerged mainly due to the innovative application of electrical engineering ideas to the field of musical instrument technology and audio technology in general. However, another musically significant technological landmark can be witnessed during the period of transitioning from *electrical engineering* to *electronic engineering*, or more specifically, with the advent of digital technology—which brought with it a new era of thinking, building, and approaching musical instrument design and production. This led to falling costs of prohibitively expensive hardware equipment, rapid shrinking of hardware footprints, and a gradual replacement of many of physical components by software modules. These changes in turn opened up an even broader realm of possibilities for music creation, music performance, music dissemination, and instrument design paradigms. The advent of digital technology and its application to the musical world was key in expanding the musical landscape and much of the music technologies we take for granted today. Digital technologies such as *musical instrument digital interface* (MIDI)[2] have created vast possibilities for music exploration through digitally codified numeric representations stored and manipulated in the virtual world. In the virtual world, no longer was it necessary for composers and musicians to hire professional musicians to play and record all of their musical parts. In the virtual world, no longer was it necessary to *redo* a recording when one made a mistake while playing a digital instrument; one could actually do it all alone *if* one had the musical knowledge, rather than musical knowledge *and* appropriate *real-time* performance skills as was the case in the past. For many instruments, one could *do* (slowly, as needed), *undo*, *redo* (even more slowly, if needed), and *edit* as necessary, thus making the possibility of a *perfect* musical performance a reasonably achievable goal: notes could be 'perfectly' aligned in time and frequency so that there were no 'mistakes.' Much like the way analog typewriters were replaced by software-based word processors, digital machines—the computer in particular—replaced many of the analog machines as well as the *absolute* need for studio musicians such as drummers, keyboard players, orchestras, and string ensembles. That is not to say that digital and MIDI-based systems have made acoustic instruments, analog technologies, and 'real' performers obsolete. This is clearly not the case. As a matter of fact, an interesting artifact that has surfaced with the maturing of digital technology and MIDI is the notion and problem surrounding *perfect music* performance itself. Digital technology and MIDI enabled perfect timing and perfect articulation of pitch. Ironically, although this may have seemed very desirable at first, the perfect 'performance' that resulted turned out to be too good, which turned out to be musically undesirable. The perfect machine performance essentially removed subtle imperfections that human performances inadvertently afforded, which listeners often preferred. Audiences interestingly favoured subtle and appropriate temporal and pitch-based imperfections. As a matter of fact, the perfect performance syndrome led to the development of digital algorithms to actually reintroduce controlled 'errors' into perfectly performed sounds created via MIDI notes and associated performance parameters. In digital audio workstations (DAW) such as *Digital Performer*, not only are there features to 'snap' incorrect human performances to rigid, mathematical time grids, but also features that enable the notion of creating 'feel' for perfectly sequenced notes. An example, is 'Randomize,' which breaks down the rhythmic precision of the machine by introducing small amounts of random errors before or after a note event.

Another artifact of the digital revolution is the democratization of music-making through affordable, sophisticated, and cost-effective technologies enabling non-experts to engage in music-making, music exploration, and music access. With such cost-effective technologies in the hands of musicians, the digital musical keyboard has perhaps become the standard *digital* musical interface as a real-time digital input device for professionals and music enthusiasts alike. Perhaps this is a reflection of a musician's familiarity of the instrument interface and its associated historical lineage (i.e. the piano) as well as today's keyboard-centric approach to music-making itself. Or perhaps it is due to other reasons including size, flexibility, and affordability compared to its acoustic counterparts. Although the electronic keyboard or the keyboard as a 'controller'[3] has found much popularity in various contexts of the music production and performance chain, novel instruments have also begun to appear with an increase in computational processing power with simultaneous decrease in hardware costs; computing machines that used to be housed in air-conditioned rooms can now be held in the palm of one's hand. With the maturing of digital technologies—hardware and software—an interesting design concept began to emerge: a decoupling of the controller (e.g. keyboard) and the sound production (sound synthesis engine) modules leading to new approaches for musical instrument design. In the commercial space, examples include Akai's Electronic Wind Instrument (EWI), various MIDI guitars and basses, the V-Accordion by Roland, numerous digital drum designs including the Korg Wavedrum, and many other examples. The majority of commercial electronic music 'instruments' still mimic their traditional acoustic instrument counterparts, however. One of the rare exceptions is perhaps the theremin, patented by Leon Theremin in 1928 (Theremin, 1928). This electronic instrument was (and is still) very innovative in that its design was like no other instrument that came before it. One of the most interesting features of the theremin is the absence of physical contact between the instrument and the performer—two independently and freely waving hands create the sounds.

With the affordability of the ever-increasing power of microcontrollers (small computers) and sensors that one can acquire readily on the Internet, activities surrounding instrument building have also begun to surface on a regular basis within professional and do-it-yourself (DIY) communities. More recently, non-traditional approaches for instrument design have begun to draw the interest of researchers and music enthusiasts, especially from the academic community. Examples include the *Radio Baton* developed by Max Mathews (Mathews, 1991), *The Hands* by Michael Waisvisz (Waisvisz, 1985), and Ron Buchla's *Thunder* (Rich, 1990). It is clear that researchers including those mentioned have helped stir the imagination of instrument builders as can be witnessed in the development of HCI courses focusing on musical applications at universities including Brown University (Designing and Playing Alternate Controllers), McGill University (Music & Audio Computing), Princeton University (Human-Computer Interface Technology), Stanford University (Physical Interaction Design for Music), New York University (New Interfaces for Musical Expression), and Tulane University (Music Performance Systems). In those types of courses, students design, engineer, and implement their own musical instruments, very often resulting in novel musical interfaces and *controllers* that deviate from traditional acoustic instrument design paradigms. In particular, as students from various disciplines (e.g. music, media studies, engineering, computer science, arts) engage in all aspects of design, engineering, implementation, and testing of new musical instruments, educational curriculums therein can, and have, contributed in attracting young students to the field of science, technology, engineering, and mathematics

(STEM).[4] STEM education has become an important point of concern with the US government given the scarcity of students engaged in the study of STEM: only 16% of American high school seniors are proficient in mathematics and interested in STEM careers; only 50% of college students who majored in STEM fields work in related professions; the United States ranks 25th in mathematics and 17th in science among industrialized nations.[5] While the STEM educational umbrella is an initiative born in the US federal governmental space, STEAM,[6] with the addition of the letter *A* (*Art + Design*) to the original STEM acronym, has furthered the scope of STEM education and additionally championed and encouraged a movement aiming to integrate *Art + Design* into curricular development. This includes K-20 and post-secondary education, while simultaneously influencing employers to hire artists and designers to drive innovation. In the realm of STEAM (Welch, 2012), music technology, which includes instrument technology, has begun to make significant educational inroads with students and faculty collaborating and exploring technological, artistic, and design through languages that encompass music, science, engineering, design, and mathematics.

Pocket Instrument Technology

In recent years, there has been a growing interest in instrument technology development due to the global ubiquity of mobile computing devices. This new platform for instrument building rapidly gained popularity with the introduction of smartphones and tablets, namely Apple's iPhone/iPad and also the various devices driven by the Android operating system. Although it can be safely argued that the smartphone does not yet provide the expressive depth and breadth of traditional acoustic and electronic instruments, the various onboard sensors (e.g. tilt sensors known as accelerometers, microphone, touchscreen sensor) have attracted the computer-in-your-pocket developer to create software (commonly referred to as 'apps') transforming a *phone* into a musical instrument. Although smartphone instruments may not be quite on par with traditional acoustic and electronic musical instruments, as mentioned earlier, it is not only the expressive breadth that makes an instrument interesting and unique; rather, it is as much about its flexibility as it is about its inflexibility or limitations that define and give character to an instrument. In this sense, one could regard the smartphone/tablet as a new type of instrument with its inherent limitations, which will be apt in generating certain types of sounds via corresponding adequate gestures, and at the same time, inadequate in generating other types of sounds through whatever limited performance techniques that may be available on the device. For example, the *Ocarina*[7] cleverly uses the microphone as a blowing interface to drive the flute-like (virtual) ocarina instrument. This software and hardware system mimics the acoustic ocarina instrument while introducing elements that do not exist on a real ocarina, namely benefits that a computer can bring to the table including performance recording, social networking features, and live performance sharing with whoever happens to be online.

Although these smartphone-based instruments are useful and expressive in many ways, as one of the main ways to interact with smartphone is its touchscreen, tactile force-feedback is an attribute that is seriously lacking. Examples such as guitar, drum, or piano smartphone apps use the touchscreen as its main means for interaction. The touchscreen, however, is less than ideal in providing the tactile feedback that we are accustomed to when interacting with physical instruments such as guitars. Although tactile feedback in smartphone instruments is not critical, having access to tactile feedback can also make a smartphone that much more expressive. One such example that provides tactile feedback for touchscreen-based

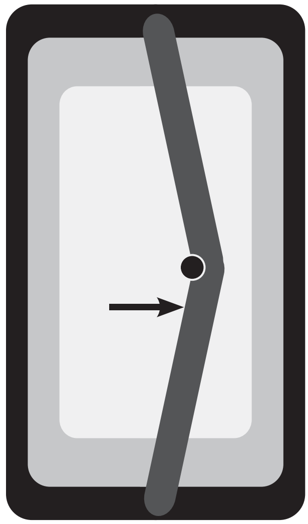

Figure 2.1 Fortissimo plucked string model.

mobile devices is the *Fortissimo* interface (T. Park, Crawford, and Nieto, 2013; T. Park and Nieto, 2013). The concept is surprisingly simple as a simple rubber band can be attached across a mobile device to coarsely emulate the physical *feel* of a string pluck. In essence, the rubber string acts as a tactile force-feedback mechanism but does not produce any actual sound. The plucking gesture is captured by the indirect interaction of the finger that is plucking the string and the touchscreen itself. In other words, a string pluck on a smartphone as configured in Figure 2.1 requires contact between the finger and the touchscreen. The plucking gesture is measured via the interaction of the finger with the touchscreen, and the plucking sound is synthesized in software on the device itself or on a separate computer that receives the gesture data wirelessly. The force-feedback that results from this design can be close to plucking an actual string when selecting an appropriate 'string' such as a nylon guitar string commonly used for classical guitars.

With the introduction of the smartphone as a potential platform for building musical instruments, the possibilities of music technology and instrument technology as a metaphor for education, especially in the realm of STEAM, are exciting considering the growth of mobile phone users: in 2012 the number of users surpassed 1 billion, and by 2017 this number is expected to reach 2.5 billion; by 2017, half of all mobile phones are expected to be smartphones.[8] As smartphones become more available to the average consumer, its possibilities as an educational platform in the context of exploration, learning, development, and STEAM initiatives becomes a realistic and practical goal. The advantages of using the smartphone as an educational vehicle for musical instrument building are manifold: (1) most, if not all, of the development occurs in the software space: the application programming interface (API) for app development is zero to minimal; (2) there is no need for additional custom hardware; (3) students learn core elements of music, engineering, computer science, and design; and (4) the outputs are tangible, real, cover theory *and* practice, and most likely are more fun than traditional classroom learning situations that require STEM components.

And Beyond . . .

We have witnessed unimaginable technological advancements within the last century in all areas including music and education. Instrument technology, in particular, has always been tightly coupled with technological innovations. In the early developmental stages of instrument building, available technologies forced 'developers' to limited exploration and design possibilities to the physical domain resulting in flutes carved out of *bones*, for example. With the discovery and control of electricity, synthetic pure *tones* generated by hardware oscillators as celebrated by the Elektronische Musik (Joel, 1997) movement in Germany became a reality. More recently, with the maturing of digital technology, *phones* as a viable platform for music-making and instrument-building have begun to take hold not just for experts but the citizen-scientist and the public DIY communities alike. Technologies that once were only available within murals of academia and research institutions are now available to the masses at low cost. Tutorials for learning the basics in microcontroller programming, implementing simple circuitry, and integrating various hardware and software modules for custom instrument building are also widely accessible on the Internet via video clips or more traditional text-based media formats. With the ubiquity of technologies formerly reserved for engineers and scientists, curricular developments in all levels of educational curriculums have also begun to take shape and develop, especially in the last 10–15 years. We live in a fascinating and exciting time where paradigms for building new instruments are constantly expanding. It is difficult to have imagined that we would be able to create flute sounds on a phone in real time in the 1990s or even the early 2000s. As a matter of fact, instrument building is no longer the practice of building physical instruments, as can be seen in some of the aforementioned examples as well as the CityGram project (T. H. Park et al., 2012, 2013; T. H. Park, Lee, You, Yoo, and Turner, 2014; T. H. Park, Musick et al., 2014), where a city itself becomes part of the instrument and performance rendered within a *locative sonification* framework that includes sensor networks, music software APIs, and visualization technologies. The educational possibilities afforded by instrument technologies are enormous, especially when juxtaposed with STEAM efforts. Although it is difficult to imagine how things will further develop and what new innovative ideas will push the areas of instrument technology and educational paradigms to new frontiers, it is clear that the stage and scope of instrument technology will expand even further while bringing its participants closer together regardless of whether they are physically in the same room, neighbourhood, city, state, country, or continent.

Notes

1. Schneider, Achim. "Ice-age musicians fashioned ivory flute." *news@ nature.com* 17 (2004).
2. MIDI: a standard digital protocol for communicating between musical instruments.
3. A controller does not make sound per se; it controls other sound-generating hardware or software devices.
4. The STEM proposal for 2015 includes $170 million in new funding to help train the next generation of innovators.
5. http://www.ed.gov/stem
6. http://stemtosteam.org
7. http://www.smule.com/
8. http://www.emarketer.com/Article/Smartphone-Users-Worldwide-Will-Total-175-Billion-2014/1010536

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3
COGNITION AND TECHNOLOGY FOR INSTRUMENTAL MUSIC LEARNING

Marc Leman and Luc Nijs

Introduction

Since the introduction of computers in music education, numerous software applications and hardware tools have been developed, leading to a variety of technology-enhanced practices to support instrumental music teaching and learning (e.g. Bauer, 2014; Brown, 2011; Dorfman, 2013; Webster, 2011). However, despite their attractiveness and their often-proclaimed added value for music learning and teaching, educational technologies remain a topic of debate. Different scholars have problematized their design (e.g. Manzo, 2011), their reception (e.g. Addessi, Pachet, and Caterina, 2004) and their implementation within the curriculum (e.g. Beckstead, 2001; Hennessy, Ruthven, and Brindley, 2005). Himonides and Purves (2010) even question whether the role of music technology for teaching and learning is actually well understood. They argue that the critical assessment of the effectiveness of these technologies should be based on empirical work that begins with well-informed theories about the alignment of technology with learning. The crucial question is how educational technologies fit with the cognitive processes and how this can be shaped for effectiveness in music teaching and learning, rather than merely providing students with a fun experience. To tackle this question requires considering the processing components that frame the interaction with technology, such as working memory, long-term memory, schema-construction and schema-automation (see Sweller et al., 1998, for more details). These processing components define a cognitive architecture that allows humans to learn from their interaction with the environment. The effectiveness of learning can then be assessed in terms of the ease with which information may be processed by the learner's cognitive architecture (Choi, van Merriënboer, and Paas, 2014). For music education, an assessment of the effectiveness of educational technology, viewed from the prism of a well-designed cognitive architecture for music learning, is indeed much needed. The connection between technology and cognitive architecture may be decisive for whether technology enhances or degrades learning.

The goal of the present chapter is to provide a cognitive architecture for technology-enhanced instrumental music learning. The classical cognitive architecture, with its focus on working memory (Sweller, Van Merrienboer, and Paas, 1998), can thereby be used as a