Zehlia Babaci-Wilhite *Editor*

Promoting Language and STEAM as Human Rights in Education

Science, Technology, Engineering, Arts and Mathematics

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This book is dedicated to the memory of Hamama Babaci, who has been a significant person in social justice and valued education of the vulnerable in the world.

Foreword I: Education, Knowledge and Empowerment

A child speaks the language of her culture at home. They know a lot about their own bodies, the names of the different parts, and their connections. They already know about food, chewing, digestion, and the separation of nutrients and waste, the nutrients absorbed in the body and the waste expelled. If they come from farming communities, they will have known a lot about plants and animals. They see, hear, smell, touch, and name what's around them, and react accordingly. They probably have created songs, stories or even drawn pictures of what is around them. Most important, they have a library of names to describe all this. Language names the world around us and stores the knowledge of the names and the named.

When in school they encounter English or any language of education that is not the mother tongue, they suddenly hear terms like anatomy, physiology, the digestive system, and suddenly, what was an integral part of their experience, sounds splendidly mental and strange.

It is the same with other experiences. From the very beginnings of their life journey, children learn that they can reach an object a little distant from them by using a stick, or if something higher, they drag a chair and stand on it. They make things to help them reach other things. They make imitation cars, airplanes, and they have names for what they do and the things that help them do it.

Then, they go to school, and in a language divorced from the one they had used to name what they make, they are confronted with words like Science, Technology, Engineering, and Mathematics. For instance, every child will have known how to count, add, divide, because they have often fought with their siblings over equal share of gifts. To resolve the conflict, they count, they put them in little piles, they take away some, and add some. They may even make marks on paper or on the ground to represent the various piles. In some games, they may mark the territory, and they resolve disputes about distance by measuring.

But when they go to school, they are confronted with Mathematical terms like, Multiplications, Division, Geometry, and Algebra. Instead of adding to what they already know in their own language, learning becomes a process of alienating them from what they already experienced and named.

Knowledge is a continuous adding to and revising what we already know to generate new knowledge that opens new possibilities. Such knowledge empowers. But for most kids who have to abandon their mother tongue to learn in another language, knowledge may confront them as a hostile force.

Education should mean knowledge as empowerment not alienation. Adding a language to what one already knows is empowerment. Being made to abandon a language that one already knows in order to acquire a new one is alienation.

The practical necessity of a common language of communication should never mean the excommunication of all the other languages. This is the challenge of education in science, technology, engineering, and Math, and all knowledge, in multilingual situations, and this book, help us think about that challenge.

Irvine, USA

Ngũgĩ wa Thiong'o
University of California Irvine

Foreword II: Creativity and Social Justices in STEAM Teaching and Learning Environments

Focusing on creativity and social justice in all phases of teaching and learning should not be viewed as an addition but as a necessary component. This book, Promoting Human Rights in Education through STEAM, emphasizes the interdisciplinary nature of teaching and learning, based on the collaboration of researchers and practitioners so that creativity and social justice focused practice is supported and nurtured. Thus, a priority is teaching all students by moving from the currently popular STEM (Science, Technology, Engineering, and Mathematics) construction, to a STEAM (Science, Technology, Engineering, Arts, and Mathematics) environment that presents a solid base to integrate all disciplines where education is precedent (Zimmerman, 2014) and fields of study keep their integrity. The integrative abilities of the arts position them to play an essential role in linking all subjects that are fundamental in diverse learning environments and include creativity and social justice emphases (Efland, 1990; Gibson & Larson, 2007; Zimmerman, 2012).

Research and practice related to the everyday lives of students need to be highlighted. It is important therefore to educate all students to use their imaginations to solve problems using STEAM skills that include arts activities using visual, aural, verbal, and somatic thinking, to facilitate development of their creativity and imaginations with just and fair relationships locally and in the world outside their familiar education environments (Zimmerman, 2009, 2010). An important goal is to promote interactions among many fields of study as to how pedagogy might be adapted through trans-disciplinary disciplines (Bastos & Zimmerman, 2015). Contemporary STEAM educators and researchers need to consider how creativity research and practice can promote social justice in an age of collaboration and use of new technologies and social media as aids in a process of preparing today's learners for universal citizenship using contemporary technologies to reinterpret traditional forms, break boundaries, and use innovative types of social communication. New digital technological environments, through modes of mass media communication, provide contexts where textural, aural, linguistic, spatial, and visual resources can be presented through images, audios, video games, crowd sourcing, social networks, and collaborative scholarship. This view supports teaching and learning as socially constructed when students learn by participating cooperatively and collaboratively, using new technological advances, and interacting with one another across local, national, and international boundaries in cyberspace (Shin, 2010; Tillander, 2011).

Research and practice, using STEAM initiatives, therefore need to be reconsidered with emphasis on development of cultural identity, technology, social media communication, good citizenship, and consideration of complex realities of the economic sector. Teaching and learning, through the intersection of these factors, is shown to have power to transform our networked, interconnected world to be dedicated to building tolerance, equality, and equity. A community of practice then results in which civic responsibility plays an important role and creativity is viewed as providing valuable in-process experiences in which everyone has rights to expression with emphasis on increasingly equitable relationships among culture, people, and economic activity (Bastos & Zimmerman, 2015). With a society-centred approach to education, that focuses on how knowledge about the world outside and beyond students' own personal experiences are presented, processes and products of culture then can be studied in a variety of contexts where social, political, religious, economic, cultural, sexual, age-based, and racial orientations are taken into consideration.

With current emphasis in the USA on standardized pedagogical outcomes, the necessity for injecting STEAM initiatives through inventiveness and fair and just relationships between students and society is evident. All educators also should consider developing educational interventions for their students, based on research and practice, that fosters creative thinking and equity, justice, and, equality to ensure that their students have access to methods of reading ideological content that is presented to them through traditional contemporary forms of communication (Duncum, 2007). Although extrinsic goals may play an important role in how creativity impacts education, intrinsic goals also perform a significant function in which the arts can make important contributions to new STEAM initiatives. With an intrinsic focus, students' own feelings of accomplishment meeting their own sets of outcomes can be brought to light as contrasted with extrinsic validation, such as meeting state STEM standards, where their work is aligned with evaluation criteria initiated by others. Through intrinsic, transformational experiences students are encouraged to become engaged in their own learning processes, set their own goals, and take risks in being creative and innovative. Generating a supportive educational environment where creativity and social equity prevails involves emphasizing student meaning-making as a prolonged engagement with a problem; encouraging being playful without constraints when working with materials; supporting risk taking by experimenting with materials and ideas without fear of sanctions against incorrect solutions, errors, or mistakes; and promoting deep involvement, passion, and imagination (Zimmerman, 2005). The time is opportune now to embrace creativity and social justice as important aspects of teaching and learning, so let's get some STEAM, and forge ahead to build integrated and equitable educational environments for all students.

Bloomington, USA

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Preface: STEAM: Why Adding the "A" for the Arts in STEM Education?

The inspiration for this book emerged from my affiliation as the former vice-president and currently elected president of the Humanities & Social Sciences Association (HSSA) at the University of California, Berkeley, USA. In my role of former vice-president of the HSSA, I had the opportunity to organize a symposium at the International House at University of California, Berkeley, on Innovative Methods in the teaching and learning of Science, Technology, Engineering, Arts, and Mathematics (STEAM) subjects in the spring of 2016. I presented a paper entitled "STEAM: Why adding the "A" for Arts in STEM Education?" a modified version of which is included in this volume. Other scholars from the Lawrence Hall of Science, the Comparative and International Education and Artists presented at the symposium and have contributed chapters to this volume. The volume draws on a unique and diverse set of authors from the USA, Norway, Denmark, Germany, India, Brazil, France/Algeria, Kenya, and Malawi. The contributions of the African and Indian authors demonstrate the linkages between local languages, human rights, and STEM subjects in education arguing that Africa and India have so far largely been excluded from the transformation that is going on in STEM pedagogy, where considerable emphasis has been placed on the use of English in teaching STEM and the development of English Language Learners (ELL).

Several of the contributions to this volume focus on curriculum changes in language and culture in STEAM subjects with a human rights perspective exploring the challenges of teaching and learning STEM subjects in local contexts through cross-cultural critical thinking in a range of countries around the world such as India, addressed in the chapter of *Purushottama Bilimoria* and *Rajunayak Vislavath*, Malawi in the chapter of *Sam Mchombo*, Brazil, in the chapter of *Ubiratan D'Ambrosio*, Norway, in the chapter of *Andre Alessandro Gasparini* and *Alma Leora Culen*, *Melanie Ekholdt Huynh* and *Ane Sommerstad*, Denmark, in the chapter of *Jeppe Bundsgaard*, Germany, in the chapter of *Beatrice Sasha Kobow* and the USA in the chapters of *Victor N. Kobayashi*, *Viet Vu*, *David Liu*, and *Kreshnik Begolli*, *Gregory Johnson*, *Helen Harrison*, *Liz Ibarra*, *Alestra Flores Menéndez*, and *Helen Min* with significant contributions by *Ngũgĩ wa Thiong'o* from Kenya, *Enid Zimmerman* and *Brad Washington* from the USA have contributed for their forewords and afterword respectively. Steve Bahri from Canada has authored the concluding remarks for the volume and Francesco De Gomes from Brazil has graciously contributed a poem to this volume.

Another inspiration for this book came from teaching students from the Masters and Credentials in Science and Mathematics Education (MACSME) programme at the Graduate School of Education at the University of California, Berkeley. This experience contributed to my understanding of the importance of using cultural and artistic concepts to facilitate teaching and learning Mathematics. My work has also benefited from using concepts from Ethno-mathematics in the teaching of Science. Inspired by the work of Prof. Ubiratan D’Ambrosio who contributed an important chapter to this volume. This inspired me to examine the use of digital technologies in the teaching of Science and Mathematics. I was fortunate to audit Prof. David Pearson’s class on Science Literacy and Prof. Jabari Mahiri’s class on Digital Devises in Urban Education at UC-Berkeley, which expanded my perspectives on science literacy and the use of digital technologies in the classroom. The collaborative project that I developed with Professor Mahiri in collaboration with Prof. Kirsten Stien from the University of Tromsø (Norway) and Prof. Inga Bostad, Director of the Norwegian Center for Human Rights at the University of Oslo, Norway, as well as our team members Dr. Lanette Jimerson and Ph.D. Candidate Lisbet Rønningsbakk, on Diversity, Technology and Human Rights was supported by a grant from the Peder Sather Foundation for which we are sincerely grateful. The grant allowed us to engage in a cross fertilization of perspectives on Science, Mathematics,and Technology between the USA and Norway as well as to link STEM education to language and human rights. The collection of chapters in this volume addresses various facets of the effort to improve the learning of STEM through the Arts.

Berkeley, USA

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Organization of the Book

This volume comprises 15 chapters in addition to this introduction with two significant forewords and an afterword, concluding remarks and a poem, all of which encompasses the rich content of promoting language and STEAM as Human Rights in Education. The chapters are divided into three parts:

I. Pedagogical Tools Integrating Linguistic and Cultural Rights in STEAM Subjects
II. Technology in Design Curriculum, Engineering in STEAM Pedagogy and the Arts
III. Pedagogical Tools in Mathematics, Ethno-Mathematics and Medicine

The contributions to Part I entitled *Pedagogical Tools Integrating Linguistic and Cultural Rights in STEAM Subjects* address and analyze the knowledge and the methodology used to improve science learning, focusing on the practice of scientific argumentation to support children in the learning of all subjects. The authors claim that creativity, imagination, and decolonization of knowledge are parts of human rights in education.

Chapter 1 entitled, "Educational Tools to Teach STEAM Subjects Integrating Linguistic Rights, Collaboration, and Critical Thinking", Zehlia Babaci-Wilhite addresses how to incorporate local knowledge using local languages as a Human Right in Education through Science, Technology, Engineering, Arts, and Mathematics (STEAM). An argument is made that education based on local language and knowledge should be defined as a basic right in order to improve the learning of Science, Engineering, and Mathematics (STEM) subjects. The author draws out the distinction between linguistic rights to education and rights in education and argues that quality education is crucial to rights in education. She frames her argument with a review of up-to-date theory and scholarly research by examining key assumptions about knowledge through the Arts that inform mainstream educational research and practice through critical thinking. The chapter argues for the need of contextualized knowledge in STEAM and reversing the current trend of de-contextualization. Furthermore, the chapter introduces new models of learning and teaching involving the value of local knowledge and local languages in the teaching and learning of STEM subjects as well as Art activities to facilitate collaborative projects forming a new platform for innovation and social justice in teaching STEM subjects for all. Her work leads to the following chapter by her colleague Sam Mchombo who through songs and games asserts the importance of culture in the learning of Mathematics and Science.

In Chap. 2 entitled, "Verbal Arts as Culturally Relevant Pedagogical Tools in Math/Science Education", Sam Mchombo argues that Mathematics and Science have traditionally had the aura of culture-free knowledge. The logic basis of Mathematics is equally deemed culture free, dependent on intelligence and manipulation of symbols and formulae for reasoning that transcend cultural trappings. In fact, logic, Science, and especially Mathematics are not merely equated with intelligence as well as the profound thinking and reasoning that have contributed to material development and technological innovations central to modern or "civilized" society, but they are equated with universal truths. In this way, mathematical knowledge stands out as being more culture free than Science since the traditional view about Mathematics has been that "two twos are four, a negative number times a negative number gives a positive number, and all triangles have angles that add up to 180°". Clearly, their intentionally abstract and general nature makes them valid everywhere. Logic, certainly in its formal/symbolic form and the formulae of logical inference invoked in argumentation seems to be of comparable texture. However, Science or Mathematics, as a subject domain, is not a cultural, without context or purpose—including the political—despite the fact that many students perceive mathematics to be a narrow set of rules and algorithms that have little or no meaning for their lives. In addition, the abstract metrical organizations of songs or games lend themselves to aspects of mathematical computations. This chapter examines how such verbal Arts could contribute to a culturally relevant pedagogy for STEM education. Furthermore, most of the countries in Africa have, like India, been deprived of their contextualized curriculum by the imposition of the European powers. Professor Purushottama Bilimoria will elaborate this through critical debates in his chapter mentioned below.

Chapter 3 entitled, "Educating For/Against Modernity, Arts and Technoculture", by Purushottama Bilimoria provides a chapter which attempts to tread the tenuous ground between modernity and the post-modern which has reverberated with debate in the second half of the twentieth century when both the theoretical framework and the political hegemony of the "Western" European tradition began to be challenged. This is achieved basically through an analysis of three issues of comparative concern between three as it were avatars of post-modernity engaged in this critical debate: Gandhi, Lyotard, and Habermas; (i) the role of the intellectual in the critique of modernity's universality; (ii) via the intellectual and intelligentsia, the pragmatics of de-conditioning the ruse of tradition, the sway of the enlightenment, re-educating (*dharma*, morality), and (iii) questioning the excesses of modernity's handmaiden, culture of technology. Eager to critique modernity, each protagonist in our inquiry seems to backtrack a little, either as a critical apologist for modernity, albeit unfinished, deconstruct and rein in on after-modernity but without an interventionist pragmatics, or mildly dissimulate but actually shame modernity in an anti-Empire challenge. The strands here bespeak *different* approaches in each to the question of education, interpreting discourse, its violence, and aesthetics. Yet the project of modernity remains un-'liquidated' in as much as the capitalist technoscience and globalization foreclose education in the arts. In line with this chapter, Rajunayak Vislavath follows up with the Indian communities' struggle to implement their local languages in school that challenges the identity and ethnicity in India.

Chapter 4 entitled "Art, Science and Language: Teaching Tools of Aborigines in India" by Rajunayak Vislavath argues that language is perhaps the most important marker of ethnicity and identity. Language lies at the core of a culture's identity and sense of uniqueness. It forms a significant aspect of the culture and identity of a person and a community. The chapter explores the ways in which the Aboriginal communities in India make use of their art, science, language, and culture to teach an understanding of nature in a scientific way. It describes how they use storytelling to pass on knowledge of nature and science in their daily life. However, the mainstream languages are dominating over local languages, so that not only the tribal languages disappear, but tribal identity and ethnicity are also swept away. As mainstream languages become dominant, not only do centuries-old tribal languages disappear, but we also see tribal identity and cultural ethnicity greatly diminished. At present, tribal language and traditional cultural art forms have been displaced and do not stand at the center of academic discourse. The mainstream community ignores any semblance of the tribal language identity. For years, the State has placed emphasis on preserving tribal identity in museums. Tribal language, culture, and traditions become objects of study and are no longer living entities which is addressed through linguistic rights. The next chapter follows the same line addressing the Foundation of Linguistic Rights in understanding agency as a fundamental right.

Chapter 5 entitled "Fictions as Heuristic Tools—Toward an Understanding of Agency as the Foundation of Human and Linguistic Rights in the Curriculum" by Beatrice Sasha Kobow examines fictions as a heuristic tool in the learning of STEM–STEAM, which has been neglected in its epistemic relevance. Fictions are pragmatically relevant and action-guiding. Importantly, they facilitate insight into the structure of agency. Considering Walton's "Mimesis as Make-believe" and its recent application in a discourse on model-making, the chapter takes the intentional-representational aspect of fictions to be one key of this epistemic point. Vaihinger's '"Philosophy of the As-if" highlights the pragmatic agentia purpose of fictions as a form of judgment. Taking these insights from Walton and Vaihinger, the argument is made that fictions promote an understanding of agency. Understanding agency is a fundamental right, which is foundational for linguistic rights in education and needs to be implemented in educational contexts. A reconsideration of the foundations of our curriculum with a view towards human flourishing will focus on different heuristic tools, such as fictions, which foster an understanding of agency.

The contributions of Part II entitled, *Technology in Design Curriculum, Engineering in STEAM Pedagogy and the Arts*, take on the debate about technology in schools and the critical pedagogical approach to teaching and learning STEAM subjects. The contributions address the broad implications that educational settings can have on STEAM subjects through Technology, Engineering, and Arts and its learning challenges.

Chapter 6 entitled “STEAM Education: Why Learn Design Thinking?” by Alma Leora Culén and Andrea Alessandro Gasparini discusses the effects of using the “Design Thinking” approach when developing STEAM curriculum. The interesting perspective in this context is the synergies coming from the Design Thinking cycle (Brown, 2008) as it addresses the Arts and Design in the STEAM context. The strength of a Design Thinking approach is the possibility of tackling complex and ill-defined problems, ranging from business to ecological and social context. These types of problems are usually named wicked, as they have no definitive solution. So far, the prevalent use of art and design in the STEAM context has been to prune the use of creativity in science, technology and engineering education. When using Design Thinking in the development of STEAM curriculum, one of the perspectives to take into account is how non-designers may learn design methods based on sensitivity to contexts, holistic understanding and empathy for user needs, present in the way designers work. The focus of the chapter is on the necessity to create dialogical spaces to support and develop adequate design languages needed in the design process. This helps students develop ways of understanding the true nature of solving complex problems. This chapter is in line with the next chapter which addresses the implementation of designed project-based learning.

Chapter 7 entitled “Using Technology to Scaffold Progressive Teaching” by Jeppe Bundsgaard addresses an encouraging consensus that has arisen in recent decades among researchers and policy organizations in favour of more progressive teaching practices like inquiry-based Science education and project-based learning, giving way to teaching that incorporates Science and Arts subjects. In this chapter, the concept of Practice Scaffolding Interactive Platform (PracSIP) addresses a number of the aforementioned challenges by organizing collaboration, structuring activities, supporting subject learning, and providing tools for production and sharing of and communication about students’ products. To explain the principles, two examples of PracSIPs are developed as ready-to-use material, and after that, the chapter points to how the principles can be used in more hand-held teaching practices using stand-alone applications. This chapter provides tools to develop collaborative learning and the sharing of information. An engineering robotic design circle elaborated in the following chapter will further develop a similar concept of collaboration.

In Chap. 8 entitled, “Expressive Robotics” by Viet Vu, David Liu, and Kreshnik Begolli describes a new Science, Technology, Engineering, Arts, and Mathematics (STEAM) curriculum that integrates expressive movement into a robotics curriculum, based on previous research projects in Arts and STEM learning, and grounded in a theoretical framework of embodied cognition and analogical reasoning. The Beall Center for Art and Technology developed a new summer camp curriculum for junior high and high school students to learn and apply movements drawn from visual Arts, theatre, and dance to computer programming and robotic design. Through student comments and project designs, the authors argue that this new robotics curriculum offers unique opportunities to engage students in an integrated Arts-based STEM curriculum. New innovations in STEAM education have opened doors for students to engage in Science where creativity is relevant and humanistic, which will be further described in the following chapter on K-12 STEAM education within the context of engineering.

In Chap. 9 entitled, "Embracing Creativity in K-12 Engineering Pedagogy" by Alestra Flores Menéndez and Helen Min propose placing an explicit focus on creativity as part of Kindergarten through High School (K-12) STEAM education. Specifically, within the context of engineering argue that the inclusion of creativity should be fundamental to a K-12 STEAM education.

The chapter examines how three key elements of an applied Arts pedagogy: promoting divergent thinking, reframing failure as a natural part of the creative design process, and incorporating reflection can enrich the engineering design cycle. The chapter proposes that broadening the scope of engineering education to foster creativity may have the potential to attract a larger number of participants to the discipline of engineering. Furthermore, creative design process applied in Arts pedagogy is deepened with the experiences of two artists with two short narratives of their work.

In Chap. 10, "Notes from Artists: Making the Invisible Visible and Art as the Bridge to Science and Interconnectedness" by Liz Ibarra's contribution is a personal meditation on the relationship between the Arts and Sciences, both disciplines are born out of our innate need for answers to the mysteries of life. Seeking those answers leads to the creation of solutions, innovations, and works of Art that looks into the future. Natural science informs the author's philosophy; and the way she approaches her own artistic creativity as a result of the influence of aesthetics, physics and biology. Furthermore, Ane Sommerstad addresses how a greater integration of Art in STEM gives the "STEAM" needed for a continuous development towards a more sustainable direction in several fields. Since the Arts can catalyse an openness to knowledge and insights from minority and disenfranchised groups, Sommerstad argues that integrating the Arts into STEM offers students the STEAM necessary for co-creation and co-learning, thus equipping them to address the social, educational, and ecological challenges facing societies. When the creative process is finally embraced by STEM, new bridges will appear to other aspects of the world in unforeseen ways and will reflect the expanding consciousness of the world.

In the contribution of Part III entitled, *Pedagogical Tools in Mathematics, Ethno-Mathematics and Medicine*, the authors address changes in Mathematics, Ethno-Mathematics and Medicine. A critique of the teaching of Mathematics is discussed with the argument that Arts facilitates the learning process. The authors demonstrate the positive effects of including Arts in Mathematics and Medicine.

In Chap. 11 entitled, "Humanity Moving Since Pre-historic Times to the Future with Creative STEAM" by Ubiratan D'Ambrosio goes beyond the concept of STEM, to present contemporary educational proposals for the entire world. The first strategies of the human species to deal with are natural facts and phenomena; these are generally embraced by the concept of Technology. Early humans generated ad hoc solutions to answer their needs for survival. From shelter to nourishment, these solutions were essential in the evolution of the species. The emotional evolution of the species led to generating ad hoc solutions to satisfy their desires. Next, probably the turning point in the evolution of the species was to recognize that how to face an ad hoc situation might be used in other similar situations. This means, recognizing that the "hows" constitute methods. This step leads us to ask why and in which circumstances methods work. This is the quintessence of Science. Understanding how and why humans venture into the new, imagining new representations of the real, thus creating Arts, and innovating with the introduction of new material constructs, thus creating Engineering. But Science required new intellectual instruments to understand the "hows" and "whys". These intellectual instruments gave rise to the origin of Mathematics. Thus, the evolution of material and intellectual instruments developed by the human species is the evolution of Technology, Science, Arts, Engineering and Mathematics (STEAM). Even ignoring historical precedence, a central topic in Education is STEAM which is a response to natural and social environment and, together with mythology, the support of culture. The chapter offers a metaphor, while STEAM was vital for the emergence of the Industrial Era, STEAM is the fuel that moves mankind into the future. Following this chapter, a reflection on how integrating STEM helps providing guidelines through Art education.

In Chap. 12 entitled, "Reflections on STEAM in Education" by Victor N. Kobayashi states with the introduction of the Arts in STEM education is welcomed as it provides the opportunity to integrate the preoccupations of scientists, technologists, engineers, and mathematicians. The emphasis on the reflections in this chapter is not an effort to make a case for the inclusion of "art education". The task is to sketch briefly how an understanding of Art itself as an aesthetic pursuit provides the opportunity to reveal the fact that the aesthetic response has been basic to driving not only the practice of STEM endeavours, but it also helps persons of all ages to regard life itself as education. Art provides a guideline for youth to find a place in the world of work, that is not only fulfilling to the self, but affirms the goals of the global society dependent on advances in Science and Technology. Current developments in Science, made possible through new technologies, increasingly make us aware of how complex human learning is, yet the holistic integration that is the aesthetic response indicates an awareness to the possibility of being a part of a global society in these turbulent times. The view of an artist regarding the complex human learning will be discussed using anecdotal observations in the following chapter.

In Chap. 13 entitled "The Synchronicity of Art and Mathematics" by Gregory Johnson discusses the premise that there is a correlation between Art and Mathematics from an instructional as well as a practical point of view. The premise is supported by an analysis of the mathematical framework of visual Art and a review of historical and contemporary empirical research into the linkage of disciplines. The chapter contains historical evidence and a discussion of cultural bias as well as anecdotal observations based on the author's artwork. The conclusion is that Art can be used as a tool in understanding quadratics, abstract principles, and the relationship of geometry to real-world potentialities. STEAM is a new model of education. Understanding its cultural significance through its artistic component can make it more accessible to the general public. Art as a tool of education can demystify Mathematics and free it from a world that is seen as belonging only to an elite. Furthermore, artistic expression as an educational tool will be discussed through Art in Medicine in the chapter below.

In Chap. 14 entitled, “The Hidden and Essential Narrative: Language and Visual Art as Learning Tools in STEM” by Helen Harrison argues that Science and Art are often viewed as highly disparate fields. However, just as Science explores and asks questions about the nature of life, Art offers an equally powerful inquiry into the forces that shape our world and the human experience. Unknown to many, Science is inherently creative and rich with narrative and personal connections. The Arts have the potential to make the stories, impact and intrinsic beauty of scientific research more visible and approachable for other scientists and the public, especially in areas such as medicine. The aim of this chapter is to use artistic expression as an educational tool to make the creative and emotional process of science, and an understanding of neurological disabilities, more accessible to people from different backgrounds. Using the three tenets of Narrative Medicine “attention, representation and affiliation” to guide the translation of this research into Art, the scientists will explore the premise of meaningful images generated during the course of research that is representative of these qualities. The artist will translate this information through a painting that expresses the scientist’s viewpoint in order to increase the understanding of their projects. In the following chapter, a medical practitioner suggests reinventing the Arts of Medicine.

In Chap. 15 entitled, “Artists as Co-teachers in the Field of Medicine” by Melanie Ekholdt Huynh argues that Medicine is both an Art and a Science. Art is important in Medicine on a humanistic level. The “Art of Medicine” has been diminished with the advancements of Science over the past century. There is now a movement among some medical practitioners and teachers that aims to reinvent the Arts of Medicine. In this chapter, examples of how to integrate Art into three different learning situations are described. The images and sounds are a mixture of visual art, music, and lyrics that can provide a rich, intense learning experience for the teaching and learning of medical skills. The narratives and the lyrics from three different music videos will be presented and discussed, followed by thoughts on how art forms such as this can be integrated into the curriculum of Medicine and other STEM subjects.

Anticipatory Linguistic Rights: Imagining Scientists-Technologists-Educators-Artists-Mathematicians Communicative Future Today

A new communicative approach to STEAM could be known
As Anticipatory Linguistic Rights it would be globally sown

To illustrate how such imaginative interdisciplinarity would come true
A creatively compiled 10-item Checklist is humbly shared with you

You have sunnily challenged this exemplification to enhance
By adding items whose actualization will STEAM advance

Checklist

STEAM professionals will have the right to

1. Have free access to online interdisciplinary encyclopedias in several languages, with information on word/phrase(ology) frequency provided for each constituent field
2. Have free access to expert interpretation/translation services while presenting at multilingual conferences, as well as to needed interlinguistic/interliteracy consultancy
3. Have multilingual spoken scientific information instantly translated into written/signed language
4. Have personally produced scientific inaccuracies duly correct by STYLENHANCER technology
5. Do graduate work in Anticipatory Linguistic Rights for scientific-technological-educational-artistic purposes
6. To write and publish scientific/technological texts in multilingual poetic form, thus DIGNIdiversifying academic writing
7. Have free communicative health treatment in a specialized clinic when one is diagnosed as a user of harmful linguistic violence, in spoken/written/signed interaction

8. Anticipatory Education, Anticipatory Technology, Anticipatory Arts, Anticipatory Science(s), Anticipatory Mathematics, etc., all of these need probing globally!

Francisco Gomes de Matos
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Part I
Pedagogical Tools Integrating Linguistic and Cultural Rights in STEAM Subjects

Chapter 1
Educational Tools to Teach STEAM Subjects Integrating Linguistic Rights, Collaboration, and Critical Thinking

Zehlia Babaci-Wilhite

Introduction

In this chapter, I will examine how the introduction of the Arts into the teaching of science, technology, engineering, and mathematics (STEM) subjects represents a new model of education that improves science learning and satisfies human rights criteria for education. I will argue that the incorporation of the Arts into an open and investigate process, based on the "inquiry-based approach", using local languages and cultural references will improve learning and strengthen human rights. This model is particularly important in educational systems which today use dominant languages and culture in their instruction, disregarding local languages, and local knowledge. In contrast to conventional approaches to education, I argue that teaching is more effective when it is based in local languages and culture which include the Arts. Therefore, I introduce a pedagogic model that expands the traditional STEM method to include the Arts. I will conclude with a discussion of the importance of national and international aimed at promoting collaborative learning as well as a pedagogical model that expands the traditional STEM to STEAM and contributes to human rights in education. This includes the introduction of digital narratives into the classroom and a virtual and international collaboration across the Art–Science divide. These narratives are grounded in both local and global culture, and they include a diversity of knowledge within the human rights framework in education. This model of teaching gives human rights its rightful place in the model of educational.

The Universal Declaration of Human Rights (1948) represents one of the great advances in global civilization (Alfredsson & Eide, 1999). Education in many devel-

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oping countries today is decontextualized, in that it is not conducted in the local language and does not promote critical thinking or intellectual inquiry. I argue that education based in a local language and local curriculum should be regarded as part of human rights in education (Tomasevski, 2006; Spreen & Vally, 2006; Babaci-Wilhite, 2012).

Education has the potential to empower students if the method of teaching provides both intellectual nourishment and a personal sense of self-respect. This in turn will bring greater self-confidence to both teachers and learners. I agree with Robeyns (2006) who writes that in order for a government to insure everyone the full benefit of an education, they must provide not only a well-developed curriculum, along with sufficient teaching materials, but also that teachers be well trained and, importantly, well paid.

Education is fundamental in developing human capability and creating individual opportunity in today's world. Crucial to quality in education is the incorporation of the UNDP principles of "Common Understanding": indivisibility, equality, participation and inclusion (UNDP, 2006, pp. 17–18). These principles are an intimate part of the social, political, cultural, religious, and artistic life of a people (Geo-JaJa, 2013; Bostad, 2013) and highlight that the safeguard of a culture's original language should be considered a human right (Skutnabb-Kangas, 2000; Babaci-Wilhite, 2015). UNESCO Convention on the Protection and Promotion of the Diversity of Cultural Expressions emphasizes the importance of linguistic diversity as part of cultural diversity (2005), and that this should apply to the education sector.

In an increasingly interdependent world, it is important to facilitate the mastery of all subject matter (Babaci-Wilhite & Geo-JaJa, 2014). The language and cultural policies in education for all countries should also be context sensitive and in addition permit countries to remain partners in the global society. In this chapter, collaborative learning is a way to start the implementation of new ideas in education, which should be regarded as a process intended to enhance new ways of learning.

This chapter highlights how Arts contribute to student participation and how fostering teamwork and collaboration for innovation and creativity in the field of STEAM subjects in classrooms and beyond provide accessibility and understanding of dominant and non-dominant languages. This chapter draws on a workshop where I provide a model of how Art can be a tool for bringing to light questions on diversity, as well as power relations between non-dominant (minorities) and dominant cultures through what Bostad calls "an investigative pedagogy". The method used in the workshop involves engaging two sets of students from Norway and the USA who illustrate the creative use of Art to establish collegiality and collaboration.

Rethinking STEM Subjects

This chapter draws on research on the teaching of STEM subjects as well as on a review of the research on problems with learning of Science and mathematics that arise from decontextualized teaching and learning. This chapter gives attention to several aspects of the problem with the aim of improving the quality of learning through different literacy using localized languages in education and local curriculum, both of which will facilitate the use of Arts. Art is culture; therefore, localized language and culture should be acknowledged in the curriculum. The term localized language is used to mean a language that is associated with the culture and traditions of the place in which it is spoken. In earlier work, I have argued that a new model of teaching and learning based on the Seeds of Science/Roots of Reading (S/R)[1] has shown to improve the learning process. The model has been adapted to the cultural context of each country acknowledging the local languages, and evaluations have shown that students exposed to this approach made significant learning improvements based on measures of Science understanding, Science vocabulary, and Science writing (Pearson, Moje, & Greenleaf, 2010). Science inquiry implies that learners search for evidence in order to make and revise explanations using critical thinking in the natural world (Babaci-Wilhite, 2017).

Academic approaches to literacy tend to regard literacy as an end unto itself, ignoring structures that undercut disciplinary learning, comprehension, critical literacy, and strategic reading. The inquiry-based approach goes beyond this superficial conceptualization of literacy, drawing heavily on the work of several educational theorists. Pearson's (2007) and Barber's approach (2005) to the role of language and literacy in the learning of Science emphasizes the importance of the theory of inquiry, which Dewey (1939, 2007) defines as a development of ideas. Furthermore, Dewey (ibid) argues that the theory of inquiry is one of the most essential skills that can help clarify the learning process and develop skills for inquiry in the context of decision-making. Furthermore, Mahiri (2011) argues that through a critical pedagogical approach, students will develop competency in STEM. Mahiri and Sims (2016) argue in their study that the impact of the critical pedagogical approach to learning and making identity connections to STEM are linguistically and culturally relevant (2016, p. 57).

In line with the philosophy of Freire's (1970) inclusive education through the integration of formal and non-formal knowledge, teaching should value learners' knowledge in non-"Western" contexts rather than oppressing them. Freire's theory has implications for the language used in schools, especially in societies with vulnerable communities.

Given that inquiry-based learning leads to better results, it makes sense that a localized language that students are familiar with will facilitate a better understanding of scientific process. Science is intimately connected to the lives of a people, and their native language should be a part of their method of learning. Language plays a critical role in cognitive learning and in the development of critical thinking (Ngugi, 1986, 1994). Drawing on scholars who address imagination and reimagining communities, acknowledging local knowledge and localized languages in educating for

[1] A science curriculum model developed by the Lawrence Hall of Science and the Graduate School of Education at UC Berkeley (USA) labelled "Seeds of Science Roots of Reading" was field tested over several years in many states in the USA. The co-founders of this model are David Pearson and Jacqueline Barber. For more information, see http://www.scienceandliteracy.org/ [accessed October 7, 2017].

Science literacy, as well as emphasizing inquiry-based learning will lead to improved teaching and learning. This can make a positive contribution to achieving quality education in STEM subjects because it acknowledges the importance of language and culture—thus the Arts.

A Methodology to Improve STEM Literacy

Improving STEM learning can be addressed by beginning with the effort to improve literacy, which will facilitate inquiry. Barber (2005) argues that inquiry is curiosity-driven and involves a great deal of reading. An in-depth inquiry calls upon critical and logical thinking that allows readers to correctly interpret the information gathered (ibid). Therefore, Pearson and Barber's approach to improving literacy by emphasizing inquiry is a real-world approach can lead to better results for both students and for Science itself. Pearson and Barbers' teaching model, in which students learn scientific concepts while they are taught how to read, write, and discuss (Pearson et al., 2010) involves students searching for evidence to support their ideas. Through firsthand (hands-on) and secondhand (text) investigations, students also engage in critical thinking to learn how to create explanations based on the evidence found. This teaching model addresses the ways that reading, writing, and discourse can be used as tools to support inquiry-based learning. It also addresses the benefit of reading, writing, and discussion when they are part of an inquiry-based Science. This has greater potential for improvements in the teaching and learning of Science, and students gain a deeper understanding of their subject where language plays a key role in quality education. Furthermore, each positive outcome in the student's course of development reveals the complex web of activities needed to bring about the change. These principles of learning address the connections between early, intermediate, and long-term outcomes and the expectations about how and why the proposed interventions will bring them about (Cervetti, Pearson, Barber, Hiebert, & Bravo, 2007). This inquiry-based approach aims for deep a conceptual understanding, an implementation of a program of planning and evaluation, and a shared cross-disciplinary understanding of the long-term goals and on how they will be reached, as well as what will be used to measure progress along the way.

This approach requires teachers to be clear about their long-term goals, identify measurable indicators of success, and to be knowledgeable about practices that meet linguistic needs, such as using graphic representations of abstract concepts (Pearson & Hiebert, 2013). The approach puts an emphasis on literacy through texts, routines for reading, word-level skills, vocabulary, and comprehension instruction. It corrects a serious problem in much of STEM teaching today, which is mainly done by bringing universal Science principles to students through non-local contextualization and non-local examples.

A model with an emphasis on cultural contextualization through the Arts and the local Language of Instruction (LoI) has great potential for improving STEM learning (Babaci-Wilhite, 2016). Such a model of instruction leads to higher goals in literacy and Science by providing students with clear instruction, opportunities for practice, and greater independence through their increased literacy to understand and communicate about the natural world. In the classroom, the teacher needs contextualized materials and teacher's guides that describe when to introduce different modes of learning such as doing, talking, reading, and writing. These guides also include detailed information on scientific subjects, instructional suggestions, and clear guidelines for what can be expected in a student's progress as they gain knowledge of specific scientific concepts that will create a meaningful picture of their world. By using a multimodal approach made up of different learning modalities (doing, talking, reading, writing), students gain an understanding of basic concepts by carrying out experiments, reading about them, and by writing about their newly gained knowledge.

For instance, students in coastal areas might read about shorelines and then investigate sand, gather evidence from sand, and write a text about its property, which leads to an understanding of the original source of the sand. Learners discuss their work (in their language), eventually forming expert groups focusing on particular sand samples. They read about shorelines, then do, then talk, then read again, then do more, then talk, then write, then talk again, then finish what they have written (Barber, 2005). Again, multiple modalities provide opportunities for learners to apply, deepen, and extend their knowledge of the learned concepts (Pearson & Hiebert, 2013).

Furthermore, learners engage in discourse, both written and oral, with the goal of communicating their evidence-based explanations. Secondarily, they then carry out a re-evaluation of their explanations and revise them based on their research. This is in opposition to the usual approach that simply adds literacy tasks onto a Science curriculum, without connecting those additional tasks directly to the advancement of the understanding from the initial investigation and does not provide explicit instruction on how to read and write Science text (Pearson et al., 2010). Recent studies have shown that learners exposed to such models made significantly greater gains in measures of Science understanding, Science vocabulary, and Science writing (Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012).

A model that links firsthand experiences, discussions, and writing to the ideas and language in informational texts not only fosters development of core Science knowledge and literacy skills, but is also crucial to improving STEM literacy, where the local contexts of everyday life contrast sharply with the North American and European contexts (Afflerbach, Pearson, & Paris, 2008). This approach resolves the problems of teaching and learning Science associated with poorly trained teachers and inadequate teaching aids and facilities. A major challenge in STEM education is how to support teachers in understanding and enacting inquiry-based instruction, as well as integrating the Arts into the classroom curriculum which will be discussed below.

Reimagining the Value of Language and Knowledge Through the Arts

Pearson et al. (2010) point out the connection between word knowledge and conceptual knowledge by emphasizing that when Science words are taught as concepts and are applied in a context to other Science words and concepts, word knowledge is consistent with conceptual knowledge. This practice of a method of education that is based on contextualization, that is, using the local LoI, leads to a rethinking of all aspects of education, both formal and informal education in and out of school. Education must therefore acknowledge culture through the Arts. This includes the non-material aspects of life such as language, social, and historical identity. Education should address both the needs of the local people and the country in which they live and should be a lifelong learning process. Education using non-localized languages and concepts cannot transmit a society's values and knowledge from one generation to the next; on the contrary, education has involved a deliberate attempt to change those values and to replace traditional knowledge by the knowledge from an alien society (Geo-JaJa, 2013).

To motivate the mind, one has to take into consideration the variations in different societies, differences in knowledge, and different ways of teaching used to achieve quality education. If education is conceived of as imparting knowledge about the world, then schooling should be regarded as only one aspect of education, since it does not cover all forms of knowledge, formal, and non-formal education. According to Freire (1970), much of the knowledge that forms the basis for schooling has its origins from another place and another time: "Knowledge emerges only through invention and re-invention" (Freire, 1993, p. 53). The students who catch on to this form of learning will be successful in school, but might actually have less knowledge in the broad sense of the word than those who do not attend school. However, education is most often equated with schooling, which does not take into account the knowledge gained outside the classroom. Therefore, it is time to think outside the classroom and rethink the value of local knowledge. Evidence from countries around the world demonstrates that the best way to learn Science is through the local language. Language is not everything in education, but without language, everything is nothing in education (Wolff, 2006). Therefore, it is important to acknowledge that local languages need a great amount of linguistic development in order to convey higher levels of knowledge as well as to function as bridges to languages of wider communication. Having several languages within one classroom gives us the opportunity to explore bilingualism and/or multilingualism, which Ngugi[2] describes "as the oxygen of culture—and monolingualism, carbon monoxide of culture".

According to Samoff (2007, p. 60), "effective education reform requires agendas and initiatives with strong local roots". In other words, local, or as it is more precisely known, indigenous knowledge, should be included in the curriculum. Storytelling is a way to safeguard local or indigenous knowledge, which can then be shared

[2]Personal correspondence with Babaci-Wilhite on March 26, 2017.

through contemporary digital media. Digital storytelling also allows for the Arts to be brought into the classroom via written text and images that are composed for the screen for twenty-first-century literacy students. Inspired by DIGICOM, a professional program to train in-service teachers in the use of digital storytelling, in collaboration with colleagues at the University of California, Irvine,[3] I implemented digital storytelling and human rights into the curriculum (2007).[4]

Collaboration for a Renewed Perspective on Human Rights

In most educational models today, the knowledge and information taught in school curricula are decontextualized. The educated person is expected to master facts, propositions, models, and cognitive skills that are separate from the context in which they were learned. Wortham and Jackson (2012) argue that the many approaches to education we know of today differ in how well they increase the learner's knowledge. Some approaches emphasize the learner as a passive recipient of information. Others encourage the learner to be more proactive in their education, to pursue inquiry, ask questions, discuss with teachers and peers.

Traditional education involves the transmission of isolated bodies of knowledge. Schools can survive as institutions because this stable knowledge and the reasoning underlying it can allegedly have value in other contexts outside of the school where the knowledge learned will be applied. Because context is not integral to the knowledge or skill, the isolated bodies of knowledge often hold little meaning for anyone outside the community that generated it. This means the knowledge learned is less useful outside the classroom given the decontextualized insular nature of the knowledge being passed on, there is generally little opportunity for students to question the claims on which the knowledge is based.

Globalization creates great convenience through the links it creates between production, communication, and technology, primarily through the use of English. But something is lost in this great cultural leveling. In contrast, STEM learners gain a better understanding of the concepts they are studying when they are taught in their local language instead of a foreign language (Brock-Utne, 2016; Mchombo, 2016). To develop conceptual knowledge, students need help in linking scientific concepts to their everyday environmental and cultural experiences to assimilate new and unfamiliar science words and concepts and to learn how to use concepts in context (Bravo, Cervetti, Hiebert, & Pearson, 2008).

Bigozzi, Biggeri, and Boschi (2002) considered that the main difference between a deep and lasting learning and a learning that is purely oral and superficial is that the former approach offers the ability to justify the data learned. Haug (2014) argues that

[3]I implemented that project while teaching "21st Century Literacies" in winter and spring 2017 at the University of California, Irvine, in collaboration with Professor Mark Warschauer.

[4]Extended to a collaborative project between the University of California, Berkeley, through a digital media in collaboration with Dr. Viet Vu, University of California, Irvine.

when Norwegian students were asked to explain how their newly learned knowledge serves them, none were able to respond since the students had developed no capacity for inquiry.

She states that students needed further clarification and explanation to develop a higher level of conceptual knowledge. This shows that knowing definitions and being able to use Science concepts in short answers is only the first step toward developing a greater conceptual understanding (Bravo et al., 2008). In order for learners to develop a stronger conceptual understanding of their field of study, teachers must include enough time for inquiry-based discussion about their empirical findings and how they connect to established Science.

Through a pre-service teacher collaboration integrating technology, culture, and human rights,[5] our team[6] developed significant conceptual frameworks and novel pedagogical competencies needed to effectively integrate innovative technologies, diverse cultures, and human rights perspectives into comprehensive designs of learning experiences for middle and high school students. The project aimed to enhance teaching competence through critical thinking within education and explore how to best prepare teachers to be most effective in designing and implementing instruction for their students to meet the challenges of a world in rapid technological change in the domains of information access and learning tools made available through digital devices. It offers an original alternative to most approaches to preparing new teachers to become professional practitioners.

Beyond teaching students disciplinary content knowledge, the new exigency is to systematically develop student abilities to think creatively, critically, and comprehensively while understanding how to access, research, and utilize traditional disciplinary knowledge as well as continually emerging digital sources of knowledge (Mahiri, 2011). These are skills students need to understand in order to work toward solutions to complex local and global problems, which we refer as twenty-first-century skills, which can be learned through 21st century literacies, by engaging better-equipped students with academic knowledge, technical competence, and research skills needed for them to critically address the challenges of a rapidly changing and increasingly complex, inter-connected world. This model of learning allowed for accessing, researching and utilizing traditional disciplinary knowledge. Furthermore, it facilitated understanding the emerging knowledge sources and working toward solutions for complex local and global issues. The kind of education teachers need must be framed by a global awareness philosophy that must be translated into a systematic method of investigative pedagogy to guide their delivery of learning in schools do not want students to just give answers, but to find the right kind of questions (Bostad).[7]

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[5] Sponsored by Peder Sather Foundation at the University of California, Berkeley (USA), in collaboration with the University of Tromsø and the Norwegian Center for Human Rights at the University of Oslo (Norway).

[6] With Jabari Mahiri, Kirsten Stien, Inga Bostad, Lanette Jimerson and Lisbeth Rønningsbakk.

[7] Proposal to Peder Sather's Grant with gratefulness and thankfulness for the generous grant from 2016–2017 renewed until July 2018.

Through virtual intellectual exchanges, the increased understanding of diverse cultural perspectives conjoined with the power of human rights perspectives to inspire and engage both the pre-service teachers and their future students in rigorous learning. Importantly, development of competencies in using appropriate technologies was central to how the collaborations between the University of Tromsø and the University of California, Berkeley, pre-service teachers mediated. This innovative collaboration has intricately linked technology, diverse cultures, cross-cultural communication, and human rights perspectives. In attempting to improve learning and make it more relevant to real-world issues and challenges, the exploration and documented viable roles for digital technology, both in the actual processes of learning for teachers and students enabled for cross-cultural and cross-continental communication between the collaborating partners. This collaboration enhanced the understanding of a significant issue across societies—how to best prepare teachers to be effective in preparing their students to meet the challenges of a changing world. Furthermore, this model offers an original alternative to most approaches used to prepare new teachers for becoming professional practitioners, in attempting to improve learning and make it more relevant to real-world issues and challenges. To summarize the outcomes, a short video was made to illustrate our collaborative process, which included workshops, virtual meetings, and our mini-conference.[8]

One of the workshops addressed the integration of Arts, with the purpose of promoting inclusion of diverse cultures, cross-cultural communication, and human rights perspectives in teaching and learning through creativity and innovation. This change in focus from STEM to STEAM needs a strong emphasis on interdisciplinary collaboration in teaching and learning at all levels in education. We provided tools and strategies for organizing and managing interdisciplinary learning and teaching based on an Art activity to facilitate inclusion of diverse cultures, cross-cultural communication, and human rights perspectives in a team collaboration of pre-service students, researchers, and artists.

Art Activity to Facilitate Group Collaboration

Art in an academic context or in any other area that involves group dynamics or collaborative interaction can serve as a model insight into process. This is especially true when dealing with the need to overcome cultural or linguistic barriers. Since Art is by its nature cross-disciplinary and universally neutral, it can be utilized in a variety of ways.

One method used in the workshop illustrated the creative use of Art to establish inclusion of diverse cultures, cross-cultural communication, human rights perspectives, collegiality, and collaboration. The students were divided into groups consisting of equal numbers, and each student was given a sheet of paper and drawing materials. They were instructed to make a random mark/figure on the paper representing

[8]See link: https://www.youtube.com/watch?v=2Y9BiAJf8Gs&feature=youtube.

themselves. At ten-minute intervals, the drawings were passed to the next student on the right, and that student added her/his symbol to the previous students work as they saw fit. The drawings were passed sequentially in this manner at ten-minute intervals until the drawing with all the additional inputs arrived at its originator. The originator then had twenty minutes to complete the drawing by incorporating the additions in a manner that they deemed appropriate. In order to level the playing field, the first round of drawing was done with the ***non-dominant hand***, while the finishing work was done with the ***dominant hand***.

After completion, there was a period of discussion and comment on the exercise followed by a display of the finished artwork. This activity had many consequences since there was no set of guidance as to how each person made their additions, and it revealed something about how students who made their input in collaboration. Some students attempted to compliment others drawings, some used the new drawing as a starting point for another direction, and some students were neutral. Another result was that students became aware of differences in perception and approach by their collaborators. The finishing work allowed the originator of each piece to express ownership of their work, while recognizing the contributions of their collaborators. In the discussion, students remarked on the flexibility and creativity of their fellows and were pleased with the results both in the actual finished work and the collaborative exercise. This activity reflects on how Art can be a tool for bringing to light questions on diversity, as well as power relations between non-dominant and dominant cultures.

Conclusion

In this chapter, I have reviewed the importance of rethinking a curriculum grounded in local context through a localized language to facilitate the integration of Arts into STEM. I have argued that this will improve learning and thus satisfy human rights. Such an approach emphasizes the importance of indigenous concepts articulated in their natural environment. Education is more than schooling; therefore, Science cannot be taught without contextualized inquiry. When STEM content is addressed through a combination of inquiry and literacy activities, students learn how to read, write, and talk STEM simultaneously. These literacy activities support the acquisition of STEM concepts and inquiry skills inside and outside the classroom as well as exploring critical thinking. Furthermore, the recent studies discussed in this chapter emphasize the connection between word knowledge and conceptual understanding. Therefore, the synergy between STEM and literacy rests upon the understanding that an active level of word knowledge in STEM (understanding of words as they are situated within a network of other words and ideas) can be described as conceptual knowledge.

The frameworks applied to word knowledge and link-making are effective in terms of enhancing conceptual learning actively engaged in making the links. Therefore, in order to enable inquiry, language facilitates the learning process and supports students in their preparation to engage with the world. Such a model, which represents an opportunity to apply a well-tested inquiry-based Science model to the teaching of Science, will lead to improved STEM literacy, scientific knowledge, and personal efficacy for students, as well as greater professional efficacy for teachers.

This renewed pedagogy would examine the whole inquiry cycle in different stages including the pedagogy of digital and critical literacy and how this could be planned for and utilized in teaching and learning. Collaboration could strengthen the teaching of STEAM subjects and allow teachers to engage learners in discussions that build on evidence collected through investigation. This process makes them more aware of what to look for in learners' responses and how to act upon these to promote conceptual understanding. This will contribute to human rights in education, improve teachers and learners' confidence in their skills in STEM, and facilitate their ability to apply knowledge to projects in their community. Drawing language and cultural perspectives into educational models make teaching and learning in the classroom more accessible. I believe that collaborative projects with include Arts activities offer an original alternative to preparing new teachers for becoming professional practitioners and students to access and understand diversity in dominant and non-dominant languages. A model that embraces and builds on STEM and integrates visual Arts through technology and films or short videos—especially the connection between word knowledge and conceptual knowledge through human rights in everyday perceptions of scientific phenomena—is the way forward for STEM education.

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Chapter 2
Verbal Arts as Culturally Relevant Pedagogical Tools in Math/Science Education

Sam Mchombo

Abstract Research has shown that in education children acquire literacy more easily in a language they already know. This leads to more effective education. The use of a community's own language in its educational system makes for the utilization of the linguistic and cultural wealth of the community and is an acknowledged right in education. Traditionally, the teaching of math and science (or STEM subjects in general) in African education has departed from the inclusion of the community's linguistic and cultural wealth largely because these subjects are projected as containing culture-free knowledge. Delivered primarily in European languages, the truths that derive from math and science are held to be culture free, objective, and universal. This paper argues that culture is important to knowledge production and that language arts contain knowledge that is relevant to STEM education. The incorporation of such culturally relevant knowledge into STEM education should provide a means by which the linguistic and cultural wealth of the community can play an essential role in the formal education of its children. It would also make STEM subjects more accessible, being approached from the basis of local knowledge. The paper

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will examine how verbal arts might get integrated into STEM education with the adoption of culturally relevant pedagogy.

Ogode! Ogode! A Children's Play Song and Game

In a village in rural Malawi, a group of seven children squat or kneel in a circle, positioned at about an arm's length from each other.[1] Each child has a stone in the right palm. Rhythmically, each child hits the ground with the stone as one of them (A) leads them in the following chant:

A: Ogode! Ogode!	Ogode! Ogode!
B: Ogode! Ogode!	Ogode! Ogode!
A: Abambo apita kuti?	Where has father gone?
B: Abambo ali kosaka	Father's gone hunting
A: Amayi apita kuti?	Where has mother gone?
B: Amayi aphika nsima	Mother is cooking nsima (the staple diet)
A: Chikati Go! Go! Go!	When it goes Go! Go! Go!
E: Chili kwa iwe, Yea! Yea! chili kwa iwe	It's at yours, Yea! Yea! it's at yours

As they begin the chant, each child hits the ground twice, to coincide with each rendering of Ogode. The pattern is retained as the chant continues, with the caesuras after abambo, amayi, and kuti, in the question lines, after abambo and kosaka, amayi and nsima, in the response lines. The pattern changes when they get to the line that says Chikati Go! Go! Go! There, in some versions, the ground is hit six times, once for each of the syllables. Then, in smooth transition, they each pass the stone to the child on the right, alternating the rhythm as they repeat the last two lines. In the last line, the caesuras come after each iwe and after Yea Yea.

The game is called Ogode, and the song that the children sing is in Chichewa, the main language of Malawi. Also known as Chinyanja, it is a Bantu language that straddles the area covered by northwest Mozambique, Malawi, and Eastern Zambia.[2] Through migrations, it spreads to Zimbabwe too. Typical of Bantu linguistic structure, Chichewa is, in its grammatical organization, an agglutinative language. Most of its words, especially the verbal elements, are internally complex. They involve the affixation to the basic verb root (VR) an array of prefixes and suffixes that encode various types of grammatical information. As a consequence, the verbal unit can easily embody such an assemblage of grammatical information that, when rendered in an isolating language such as English, easily translates into a full-fledged sentence. In its structural organization, the VR and the suffixes comprise a significant sub-unit, the verb stem (VS).

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[1]The number of participants is not fixed. It just has to be more than one.

[2]As a consequence of the policy that made Chichewa the national language in Malawi in 1968, the majority of Malawians are functionally literate in that language despite the presence of other languages in that country (cf. Mchombo, 1998).

The VS is the domain of suffixes that affect 'argument structure' or transitivity patterns, i.e., the number of (pro)nominal arguments that the VS requires within the simple clause structure. In Chichewa, the VS is also the domain of vowel harmony (Mchombo, 2004) and, further, displays an accentual system as opposed to a pure tone in its prosodic structure. The suffixes, tonally unspecified, get the tone of the VR spread to them, giving the effect of an accentual system (cf. Moto, 1989; Mtenje, 1986).

Prefixal elements, arguably clitics, are attached to the VS (Mchombo, 2002a, 2002b). The clitics and the suffixes, different in syllable structure, contribute different kinds of grammatical information. The suffixes affect the transitivity patterns or 'argument structure' of the verb stem, while the prefixal material, the clitics, contributes information relating to agreement with the verb's arguments (subject and object), tense and modal elements, negation, etc.

The nouns in Bantu tend to involve limited morphological complexity. At the minimum, the noun in Bantu comprises a prefix and a nominal stem. The former encodes information necessary for agreement patterns with the noun's qualifiers and with the verb (Mchombo, 2004). An illustration of the linguistic structure of Chichewa is provided in the sentence below[3]:

1	Mkângo	si-ú-na-ká-ngo-wá-phwány-a	maûngu …
	3-lion	NEG-3SM-past-go-just-6OM-smash-fv	6-pumpkins

'The lion did not just go smash them, the pumpkins…'

In this sentence, the word mkângo is, morphologically, m-kângo. The prefix, a syllabic nasal (contracted version of 'mu', as evident in nouns whose stem is monosyllabic, e.g., mu-nda "garden"), marks information relating to gender class and number (in this case, singular). The information is involved in agreement patterns with the noun's qualifiers and with the verb. The nominal stem is—kângo. The gender classes group nouns in Bantu into an elaborate classificatory system distinguished by alternations in singular/plural markings. The verbal element, si-ú-na-ká-ngo-wá-phwány-a, with the grammatical information encoded in the prefixal material (clitics) dutifully spelt out, is a single word. Significantly, there are no verbal suffixes included. These would affect the presence or absence of those clitics that function as pronominal arguments of the verb (cf. Bresnan & Mchombo, 1986, 1987). An example that shows the presence of verbal suffixes is the following:

2	Mkângo	u-da-wá-ómb-an-its-il-á	mbidzi	alenje
	3-lion	3SM-pst-2OM-hit-recip-caus-appl-fv	10-zebras	2-hunters

'The lion made the zebras hit each other for the hunters'

[3]The following abbreviations are used to indicate the various morphemes in the glosses of the sentences: appl = applicative; caus = causative; fv = final vowel; NEG = negation; OM = object marker; pst = past tense; recip = reciprocal; and SM = subject marker. The numbers associated with the nouns indicate gender class. An acute accent over a vowel indicates high tone. Low tones are not marked. The remaining Chichewa expressions, songs or proverbs, will not get marked for tone.

These examples highlight the agglutinative nature of Chichewa in its grammatical structure. The verbal element, despite being indicated with dashes to separate the morphemes, is a single word with full lexical integrity (cf. Bresnan & Mchombo, 1995).

In its phonological structure, Chichewa has open syllables, common in Bantu languages. Thus, the vowel marks syllable boundary. A word such as 'chikati', used in the song, has three syllables chi-ka-ti. Grammatical processes of affixation preserve the general (consonant) vowel (C_oV) syllable structure of the language (Mtenje, 1980). In its suprasegmental (or prosodic) phonology, Chichewa is a tone language, displaying grammatical and lexical tone, as illustrated below, where the noun prefix in m-tengo is a syllabic nasal:

3 Mtengo 'price' versus mténgo 'tree'

4 Si-á-ná-píte 'they did not go' versus si-a-na-píte 'they have not gone yet'

There is also intonation to mark questions, interjections, declarative statements, etc., sometimes aided by specific grammatical or lexical markers. For instance, the word kodí is normally used to signal a question, sometimes overriding the intonation pattern. However, its absence makes it mandatory that intonation signals the proper construal of the expression as a question or a statement. The language also has stress assignment on words. Typical of Bantu languages, the stress regularly falls on the penultimate syllable of the word. In verbs, suffixation provides useful evidence of stress assignment in that the stress "visibly" moves to the penultimate syllable as the suffixes get added.

Rhythm and Meter in Chechewa

In their 2016 presentation, Kalinde and Banda (2016), henceforth (K&B), argued for the inclusion of children's play songs for teaching and learning. The songs involve aspects of

(i) Collaboration;
(ii) Holistic education involving physical, social, emotional, and cognitive development;
(iii) Participation: active, also leading to incidental learning.

The program of including children's play songs for teaching and learning has benefits that go beyond the aesthetic side of singing and, as is usually the case in oral cultures, dancing as well. Songs involve, by their very nature, the organization of linguistic expressions into regular patterns. Facilitated by rhythmic structure, the patterns comprise metric organization. Meter involves timing of sub-groupings of linguistic units at regular temporal intervals. Languages differ with regard to the linguistic devices that they exploit to mark the sub-groupings. In English, a stress-timed language, there is exploitation of stress patterning. Thus, the succession of unstressed and stressed syllables gets regularized to adhere to a particular timing scheme. These are the (poetic) feet of English prosody. Patterns such as those referred to as anapestic, iambic, or trochaic capture such isochronous stress timing, marking feet of varying lengths. Nursery rhymes sensitize children to the metrics of their languages.

The account of the linguistic structure of Chichewa provided above is relevant to the discussion of its metric structure. The agglutinative morphological structure of the language, allowing for "sentences" that may consist of single "words," and stress assignment confined to a predictable location within the word, makes for meter that is not dependent on the intervals between stressed syllables. Put bluntly, Chichewa is not a stress-timed but, rather, a syllable-timed language. The units that get regularized comprise determinate quantities of syllables. In one study of Chichewa metrics, such a grouping of syllables was designated as Phande (plural mapande) (cf. Mchombo, 1977). Poetic license arises when there is departure from rules of ordinary grammar in order to adhere to the devised metrical organization, either grammatically or prosodically.[4] In oral performance, such syllable groupings get marked with extra-linguistic instrumental accompaniments, such as the handclap, the drum beat, the pestle beat (when women are grinding grain in the mortar) or, as in the children's play song above, hitting the stone on the ground. The children learn to recognize the metric designs of their language. These aid in the development of cognitive capacities. As part of social development, they become aware of the punitive measures that get meted for infringement of requirements. Let us look at some of these.

As the children sing the song and play, they develop knowledge and abilities that include the following:

(a) The mathematical ability of counting: The sizes of mapande involve certain quantities of syllables. They need to know the quantity. In the line where they have to hit the ground six times, they need to know how to determine syllable boundaries, how many syllables are involved, so that they can execute the correct movement.
(b) Physical development: The child must be able to move the limbs or body in timely or rhythmic fashion to hit the ground or place the stone in front of the next individual at the right times. This also requires sensorimotor (eye–hand) coordination.
(c) Determination of actionable space: The child must be able to move objects within delimited space, specifically, to the child positioned to the right.
(d) Speed: The child develops an awareness of the rate at which an object can be moved over space with respect to the time required to move it there. The time is determined by the rhythmic or metrical beat.
(e) Accuracy: The child must shift objects in the allowable space within the allowable time with an acceptable degree of accuracy. This is with regard to where the object is to be located. It must be in front of the receiving child.

[4]In the song, the line Amayi aphika nsima lacks the present tense marker. This is to ensure that the line does not contain more syllables than the metric design allows.

(f) Coordination and cooperation: The child develops awareness of cooperating and coordinating with others. The play demands social interaction, necessary for ultimate socialization in the society.
(g) Linguistic development: The child must have mastered the language of the society in order to participate. In brief, the child must be developing cultural identity through the acquisition and use of the local language.
(h) Sensitization to gender roles: The information provided in the song about the different chores that the parents are engaged in sensitizes the children to gender roles in society.
(i) Rewards and punishment: The child who breaks the rhythmic movement through either mistiming the reception of the stone or failing to deliver the stone to the next person in timely manner, or whatever, winding up with several stones piling up in his/her base, gets punished through elimination. The winner is the one who executes the movements flawlessly all the way to the end, remaining the only one "standing," after the elimination of everyone else.

Such plays, alongside other cultural activities, equip children with knowledge some of which is of relevance to science and math or, in general, STEM education. The term is used here to designate Western science that predominates in formal schooling. It needs to be said that it is not the only scientific tradition. There are different kinds of science. Feyerabend noted that people from different social backgrounds will "…approach the world in different ways and learn different things about it. People survived millennia before Western science arose; to do this they had to know their surroundings up to and including elements of astronomy" (Feyerabend, 1988, p. 3).

In the play song and game above, the children deal with such issues as manipulation of objects in space and time, adhering to exact specifications of mathematical calculations and synchronization. When this knowledge, acquired within the sociocultural context, is incorporated into the school curriculum, the curriculum gets to adopt a culturally relevant pedagogy. The children use the local knowledge as the basis for incorporating new "global" knowledge, as they continue along the path of cognitive and social development. In fact, the standard methodological approach to cognitive development is that it situates it within the sociocultural setting. Sociocultural and ecological research supports a view of identity and learning as being deeply informed by social context. This is consistent with the tenets of social constructivism which characterizes learning as a social process mediated by the learner's environment and where the prior or indigenous knowledge of the learner is of significance in accomplishing the construction of meaning in the new situation. All learning, it is argued, is "…mediated by culture and takes place in a social context. The role of the social context is to scaffold the learner, provide hints and help that foster co-construction of knowledge while interacting with other members of the society" (Jegede & Aikenhead, 1999, p. 45).

Emerging from this research is the theory that social context influences learning and identity through the organization of activities in which people participate and through the values, norms, and expectations conveyed in those activities (cf. Nasir, 2012; Peele-Eady, 2011). In other words, social and cultural contexts and processes are central to learning. In fact, comparative educationalists emphasize the importance of context in understanding education (cf. Kwok, 2017). As such, "understanding learning requires a focus on how individuals participate in particular activities, and how they draw on artifacts, tools, and social others to solve local problems" (Nasir & Hand, 2006, p. 449).

The language arts, as exemplified here, seem to play a crucial role in the development of knowledge some of which facilitates acquisition of STEM knowledge. Culturally, relevant pedagogy would strive to incorporate such knowledge as the basis for acquisition of facets of knowledge that go beyond the local.

African Proverbs as Didactics

While African musical arts, integrating singing, dancing, drama, storytelling, action, play, etc., contribute immensely to physical, cognitive, and social development, the knowledge is also enhanced through other aspects of traditional education. Crucial is the knowledge that is delivered through African proverbs. Banda (2008) describes proverbs as 'capsules' full of wisdom. They have also been described as 'libraries' of wisdom, norms, and beliefs. They are dynamic and are not bound by time or place. In addition to inculcating into adolescents what the elders consider as 'truths,' proverbs also function to warn, offer advice, praise, teach a moral, rebuke, etc. Proverbs play such a crucial role in communication in the African context that Chinua Achebe described them as "the palm-oil with which words are eaten" (cf. Achebe, 1994). They embody knowledge gained over years and are vehicles for the dissemination of such knowledge in order to give life lessons to new and wider generations of people.

Proverbs fall into different categories. These include proverbs that are appropriate for use in judicial cases or legal matters; those necessary for building character or personal integrity and morals; and proverbs for 'various' occasions (cf. Kumakanga, 1975). Some of the ones included in the latter group deal with such scientifically or philosophically relevant notions as cause and effect, appearance and reality, etc. The proverbs are, in many respects, pithy 'shorthand' for philosophical/scientific outlook informed by cultural norms or values, and rooted in African experience. They have didactic value and can be invoked as rhetorical devices in relevant situations of discourse. It is for this reason that they are of intellectual and scholastic value. Some proverbs from Chichewa provide relevant illustrations. Thus, for cause and effect, one gets the following:

5 Umanena chatsitsa dzaye kuti njovu ithyoke mnyanga
'talk about what caused the (dzaye) fruit to fall down and break the elephant's tusk'.

This proverb embodies admonition to seek the causes of observable facts. The dzaye fruit fell down and broke the elephant's tusk. The broken tusk, the dead elephant, and the dzaye fruit lying nearby are the obvious pieces that constituted the immediate facts. Missing is the cause of the fruit's fall. The facts presented need to be evaluated against the causes. The following proverb has comparable import:

6 M'chiuno mwa mwana simufa nkhuku
'the waist of a child is not cause for slaughtering a chicken; or,
a chicken does not get killed because of the dexterity of a child's waist movement (in dancing)'.

The cultural context here is that beautiful dancing gets rewarded with gifts. A major gift to the dancer in the Chewa tradition is a chicken.[5] The proverb instructs that compliments for the beautiful dancing of a child (the effect) should go to the elders or parents. They are the ones who trained the child (the cause). A corollary of that relates to a bad-mannered, disrespectful child (the effect/result). The normal inquiry is that of whose child (the cause) he/she is.

The need to go beyond appearances in order to get to reality is conveyed in such proverbs as the following:

7 Chikomekome cha nkhuyu mkati muli nyerere
'a fig fruit may look beautiful/juicy but inside there are ants'.
8 Maonekedwe a kunja apusitsa
'Outside appearances can be deceptive'.
9 Maso apusitsa
'Eyes can fool a person'.

Some proverbs instruct individuals in the art of diligence or patience. The search for the reality that lies beneath appearances can be painstaking; specialists are the product of tenacity, especially in the face of adversity or discouraging conditions. They do not quit, lest they should do so at the point of success. In Swahili culture, one gets such a proverb as 'mtaka cha mvunguni sharti ainame' (the person who wants what is under the bed must bend). The thrust of the proverb is that one must strive for whatever one wants or desires. Chichewa provides such examples as:

10 Kuona maso a nkhono n'kufatsa
'to see the eyes of a snail one needs patience'.
11 Nyanja ya bata siisula mmalinyero wa luntha
'a calm sea does not train a skilled (experienced) sailor'.
12 Nguluwe inalira msampha utaning'a
'the wild hog hollered (quit) when it was about to break loose from the trap'.

The need for cooperation to achieve the desired goals is expressed in the following proverbs:

13 Chala chimodzi sichiswa nsabwe
'One finger does not crack (kill) lice'.

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[5]For the Chewa, the chicken has always been the major delicacy and of significant cultural value. When a visitor has to be made to feel truly welcomed, the host(s) kill(s) a chicken for him/her. In disputes, when the ruling is passed, the fine for the offending party to pay the offended party is, normally, stated in terms of number of chicken(s).

14 Ichi n'chiyani nkulinga muli awiri
'Lit: "'what's this?' depends on there being two of you"; i.e., one needs a companion to express puzzlement to'.

Then, there are proverbs such as the one below:

15 Fupa lokakamiza silichedwa kuswa mphika
'A bone that is forced into a cooking pot quickly breaks the pot'.

This proverb instructs that contained items cannot be larger than their containers, physically and/or metaphorically. This is relevant to the concept of inclusion in set theory.

In general, proverbs embody the wisdom of the society which deals with holistic situations and operations in the density of real life rather than abstractions. Wisdom includes precepts that guide individuals in dealing with issues of life and living based on experience. Those may not necessarily coincide with matters of formal logic, narrowly defined (cf. Kazeem, 2010). This has not deterred scholars from efforts so assimilate African proverbs to principles of formal logic. For instance, Ngalande engages in an analysis of some proverbs in Nyanja (Chewa). While the analysis has intrinsic intellectual value, its thrust seems to lie more in 'propaganda'. The objective of the analysis is to show that the wisdom in African proverbs has a logical basis. The upshot of the analysis is that Ngalande adopts the view that "…logic, ordinarily understood as intelligence, is the basis for wisdom. In logic, wisdom is equated with the appropriate use of syllogisms. Thus, a wise person is expected to use syllogisms that are valid and sound to a greater degree than would an ordinary person" (Ngalande, 2011, p. 105). The concluding observation is that the analysis shows that "proverbs contained the highest percentage … of valid and sound syllogisms," leading to the view that "proverbs truly represent the wisdom of the people" (ibid). The equation of logic with intelligence and the demonstration that Nyanja proverbs contain sound and valid syllogisms seem to underscore the intelligence inherent in African wisdom. Assuming that the analysis is valid, it does point to the relevance of incorporation of such knowledge when introducing math, science, or logic to the students. In other words, language arts contain knowledge some of which is germane to STEM education. A culturally relevant pedagogy in modern formal education would endeavor to include such knowledge, among other things, to provide the children with a culturally grounded knowledge base for learning new material.

K&B tout, *inter alia*, cultural play songs and proverbs as "indigenous knowledge systems that can be used in teaching and learning." Recently, in Malawi, Nanzikambe Arts has got into a project of adapting Malawian Folktales for Stage Drama, a project designed to help preserve the diminishing heritage of imparting knowledge through folktales and/or storytelling. More importantly, the project will make significant contributions to the availability of materials to the education curriculum in Malawi in the teaching of Creative Art as a subject.[6]

[6]https://www.nyasatimes.com/nanzikambe-arts-adopting-malawian-folktales-stage-drama-education-purposes.

This underscores the need to include the rich cultural heritage of the nation in the educational program. Culturally, responsive educational curricula should positively impact children's cognitive development, their evaluation of self-worth and identity, as well as enhance their appreciation of the knowledge obtained from the sociocultural context. However, the inclusion of such African Indigenous Knowledge Systems (AIKS) is not standard in the schools. This accounts for the newsworthiness of projects such as the one mentioned. This omission delimits the concept and content of "learning" in unfortunate ways. Education, certainly within the African context, is viewed as a lifelong process. The Swahili proverb 'elimu ni maisha si vitabu' which translates to 'Education is in life, not books' implies that important life lessons are part of a person's day-to-day experiences. The implication is that education should be relevant to the livelihoods of learners.

The education of the young to turn them into virtuous, well-mannered, and cultured citizens crucially involved the wisdom embodied in African proverbs. The saliency of early learning in African culture was emphasized through proverbs. For instance, in Swahili one gets the saying that 'mti mkande ungali mchanga' (a tree must be straightened while still young), or 'udongo ukande ungali maji' (clay must be modelled while still wet). Another Swahili saying states that 'mtoto umleavyo ndivyo akuavyo' (the way a child is brought up is the way they grow). The Chewa have a saying with equivalent import that states that 'mmera ndi poyamba' (plants should be tended to when they are still green or 'early care pays/matters'). These proverbs reminded parents and other socializing agents that the child's character will be a reflection of the socializing process that the child undergoes. Thus, the ideas on education in the proverbs in African societies indicate the fact that "education was seen as a lifelong process starting at birth; that education was not confined to the classroom or formal education institution. Therefore, educators need to look at education as a process that starts in the family before the school takes over. Therefore, there must be continuity between family education, school education and adult education as well as other informal places in which one learns. Modern educational planners who take such a view would be more comprehensive and inclusive in educational planning" (Abubakar, 2011, p. 71). Yet, the Eurocentric curriculum that is central to both the early and later education of African children remains singularly glaring in its omission of this knowledge. What factors, then, militate against the incorporation of such indigenous knowledge systems into the curriculum and in the development of culturally relevant pedagogy?

On the Objectivity and Universality of STEM Subjects

Every society has an educational program, construed as a system of training the young to become responsible citizens. This includes the transmission of cultural values, morals, specialized skills needed for survival, religious beliefs, legends and history of the community, customs and traditions pertaining to various aspects of life and living (including dying), rites of passages in life's transitions, duties, and responsibilities associated with gender roles. Such an education, grounded in the sociocultural context, includes scientific and mathematical knowledge.

In mathematics education, the term ethnomathematics refers to the study of the relationship between mathematics and culture. Often associated with cultures without written expression, it may also be defined as the mathematics which is practiced among identifiable cultural groups. By the same token, relativizing science to culture gives rise to indigenization of science. Such indigenization of science is what Gitari has termed "Endogenous science," defined as "the scientific literacy that is inspired by local needs, but crafted using knowledge from all domains of life" (Gitari, 2012, p. 31). The problem with such labels is that they have the import of making the science or math education so construed as, in some ways, departures or deviations from the "norm." What then is the "norm"?

Education in Africa routinely gets identified with formal schooling, introduced during the era of European colonialism. While colonialism was all about the assumption of political power and the extraction of economic resources, the Europeans also introduced their religious beliefs and practices, imposed their cultural values, and, significantly, introduced their system of education. A significant problem with colonialist-based education in Africa is that "oftentimes learners find the Western-style classroom practice engendered by the school system far removed from their everyday cultural practices" (Banda & Banda, 2016, p. 83).

A crucial component of the colonialists' education in Africa was the use of the written medium. African societies had, traditionally, thrived as oral communities. The centrality of literacy to formal education resulted in bolstering colonialists' political, economic, and cultural domination through educational programs that emphasized acquisition of knowledge encoded in written form. Inevitably, this represented Western Knowledge Systems (WKS) (history, systems of government, culture, science, beliefs, etc.), delivered in the languages of the colonialists. Increasingly, knowledge was defined as "…what can be extracted from a written page" (Feyerabend, 1987, p. 110). The acquisition of that knowledge and of the languages used to acquire it got identified with intelligence and civilization. AIKS or African culture was, consequently, assumed to be nonexistent or, if acknowledged at all, held to be totally unscientific and of inferior value. African languages did not even count as such (cf. July 1992). Education became a program of knowledge acquisition in diverse disciplines that was codified in written form (cf. Mchombo, 2016).

WKS of Eurocentric education in Africa emphasized, for the colonized, "…education for obedience and subordination and marginalization, as the dominant institutions require," rather than "for freedom and democracy" (Chomsky, 2000, p. 48). In this, STEM subjects played a major role. These were deemed to be of universal validity, encoding objective knowledge that, putatively, was not expressible in the "rudimentary" communication systems of preliterate societies. As a consequence, African education retained, not only the Eurocentric curricula but, significantly, European languages as languages of instruction (Bamgbose, 1991; Mchombo, 2017).

A crucial feature of Western scientific practice is that scientific knowledge consists less in what it is but more in how it is arrived at. It is the methodological aspect that is central to science. Facts are observed and hypotheses formulated that get evaluated against more facts for empirical (dis)-confirmation. The theories that emerge contribute to an understanding or explanation of the facts. The falsifiability of scientific hypotheses means that scientists avoid dogma.

Science, math, as well as logic, are regarded as comprising knowledge that is culture-free, objective, and universal. Science traverses cultural and national borders, and seeks universal truths, using unique methods that, ostensibly, are not shackled to any culture-specific beliefs or practices. Advances in technology and other benefits to society that get attributed to scientific practice and investigation have contributed tremendously to its respectability in modern society and to its dominance in intellectual activity. Thus, science thrives on formulation of claims, hypotheses, theories, etc., that are supported by reasons or empirical data, are susceptible to refutation, have logical coherence, and are not tied to the cultural beliefs of any one community.

The claims of the objectivity and universality of science, math, and logic, in concert with their being culture-free and instrumental to technological innovations, have done a lot to obscure their role in the dominance of Western values and WKS in the educational programs of other nations. In truth, science or "mathematics, as a subject domain, is not acultural, without context or purpose including the political" despite the fact that "many students perceive mathematics to be a narrow set of rules and algorithms that have little or no meaning to their lives." (Martin, Gholson, & Leonard, 2010, p. 14).

The reality is that mathematics is a discipline that has thrived within a certain cultural context and, "the enterprise of mathematics education is no different than other societal contexts characterized by power relations" (ibid., p. 21). Indeed, science and math are components of epistemologies of societies, theories of knowledge that make basic claims about the nature of knowledge, who can know, what we can know, and the determination of evidence for the claims made. And, "[E]pistemologies do not exist outside of the people who construct and use them. Individuals and groups adopt various epistemologies at different points in time to make sense of the world. Epistemologies are also not equal in status, in society at large, or in the academic community. Epistemologies are situated within political, historical, and economic contexts that can provide power and legitimacy to their knowledge claims" (Hunter, 2002, p. 120).

In addition, the knowledge embodied in "science" that is associated with formal schooling is, itself, the product of specific methodological aspects of inquiry fostered by, and supported within, specific sociocultural–politico-economic contexts or environment. It is not any more culture-free or objective or universal than other forms of knowledge. The methodological approach may give it a degree of uniqueness, but it is not culture-free.

The claims of objectivity, universality, or culture independence of scientific knowledge derive from power relations or political dominance of the agents of knowledge production. While those notions get invoked to suggest that the knowledge is "…valid irrespective of human expectations, ideas, attitudes, wishes" (Feyerabend, 1987, p. 5) or as "…a measure by which theoretical suggestions and practical achievements must be judged" (ibid., p. 99), they are notions that are "older than science and independent of it" arising "when a nation or a tribe or a civilization identified its ways of life with the laws of the (physical and moral) universe and it became apparent when different cultures with different objective views confronted each other" (ibid). In other words, they are notions that have to do with political dominance or power relations.

In general, scientific knowledge is generated and validated by a scientific community that excludes the general public. By social division of labor, "…modern society entrusts the cultivation of science to a highly specialized professional group, characterized both by expertise and extreme commitment to science as a social institution. What should, in philosophical principle, be done by all men, is given into the hands of proxies, who bear collectively the powers and the responsibilities of science within society at large" (Ziman, 1978, p. 125). This gives science a particular cultural outlook, a culture of science, leading to the view that "…to learn science is to acquire the culture of science. To acquire the culture of science, a pupil must travel from their everyday life-world to the world of science found in their science classroom" (Jegede & Aikenhead, op. cit., p. 47).

This "scientific community" has, traditionally, consisted of white males, excluding people of color or, for the great part, women. Thus, the *scientific community*, empowered to formulate theories that make basic claims about the nature of knowledge, acquires the mandate to determine who can know, how we can know, and what counts as legitimate knowledge. Western science taught at school is often shown to be more superior to knowledge within the local culture. Iaccarino states it succinctly that "…colonization by Europeans destroyed much of […] indigenous knowledge and replaced it with the European educational and political system that consequently devalued what was left of it" (Iaccarino, 2003, p. 4). This frowning on African epistemologies contributed to the view that African people had no science (see Maddock, 1981). In Africa, as elsewhere, the reality is that "…indigenous languages, knowledges and cultures have been silenced or misrepresented, ridiculed or condemned in academic and popular discourses" (Tuhiwai-Smith, 2012, p. 21).

This constitutes cultural domination and exercise of political power rather than mere production or transmission of knowledge. STEM knowledge is, thus, imbued with the values of the cultural milieu of its agents of knowledge production. Baraka (1971) held the view that machines have the morality of their inventors. In other words, "science is part of culture, and how … science is done largely depends on the culture in which it is practiced" (Iaccarino, op. cit., p. 1).

Language Arts and Culturally Relevant Pedagogy

The language arts, as exemplified by the children's play songs, games, proverbs, etc., contribute toward the early formation of math and science knowledge. The incorporation of that knowledge into the curriculum should contribute to better understanding and appreciation of STEM subjects. The factors that militate against the inclusion of such culturally relevant knowledge seem to reduce to one aspect of the characterization of ethnomathematics, to wit, that it is often associated with "cultures without written expression." The tyranny of the culture of literacy and subservience to knowledge accessible in written form underlies the lack of appreciation of culturally relevant knowledge furnished by the oral tradition. This is unfortunate.

It has been noted that the sciences, and mathematics in particular, require the acquisition and coordination of three kinds of knowledge: *Conceptual Knowledge*, *Procedural Knowledge*, and *Utilization Knowledge*. These comprise, respectively, "the ability to understand the principles that underpin the problem; the ability to carry out a sequence of actions to solve a problem; and, the ability to know when to apply particular procedures" (Cole & Cole, 1993, p. 482). Research has shown that "…most children arrive at school with some of each kind of knowledge, and cross-cultural research reveals that even societies with no tradition of schooling and literacy use methods of counting and solving arithmetic problems…" (ibid). Education, as the program of equipping the individual with socioculturally determined knowledge shaped by local contextual parameters, should strive to incorporate such indigenous or traditional knowledge in the curriculum, especially in the early stages of child development.

The children's lifeworld cultural knowledge constitutes the foundational knowledge against which the new knowledge of the culture of Western science can be evaluated and absorbed. Getting into the culture of science of formal education constitutes a version of "culture crossing" (cf. Jegede & Aikenhead, op. cit.) engendering inevitable "cultural clash/conflict" characteristic of "cultural contact" and the ensuing power struggles. With colonialist education, the culture of science was generally at odds with a pupil's lifeworld. Science instruction tended to "…disrupt the pupil's worldview by trying to force that pupil to abandon or marginalize his or her life-world concepts and reconstruct in their place new (scientific) ways of conceptualizing. This process is assimilation" (Jegede & Aikenhead, p. 47). In many cases, the effect of assimilation was to alienate pupils from their indigenous lifeworld culture, thereby causing various social disruptions.

Decolonization of Education

K&B decry and disapprove of the current reliance on Eurocentric approach to the use of local knowledge and approaches in education which equates "alternative knowledge to that offered in schools" with "Ignorance," or "alternative medicine to Western medicine offered in hospitals" with "Witchcraft." The stand that K&B adopt with regard to the content of African education resonates with the continuing activism about decolonizing the curriculum in African education which, still shackled through its content and languages of instruction to foreign knowledge systems, reinforced through globalization, science, and technology, is in need of "liberation." In the preparation of children to attain "global" knowledge and adjust to concepts in STEM education, the utilization of the relevant foundational knowledge that is furnished, in part, through the language arts is imperative. This, effectively, makes the acquisition of the new knowledge build on previously acquired "local" knowledge. This is central to learning, characterized by shifting from the known to the unknown.

Success may also depend on the language(s) used for instruction. The language arts, the children's plays, songs, games, proverbs, word games, etc., are in the local languages, the languages of the society. The use of the children's first language is crucial in their subsequent adaptation to acquisition of foreign languages and the knowledge delivered in them. The strong argument in support of using a community's own language in its educational system is that "it provides a means by which the linguistic and cultural wealth of the community can play an essential role in the formal education of its children, thereby enabling knowledgeable members of the community to participate in ways which might not otherwise be open to them" (Hale, 1974, p. 3). Besides, literacy in local languages is, arguably, key to sustainable development in Africa (cf. Trudell, 2009). Children can acquire literacy more easily in a language they already know, leading to more effective education. In turn, this can contribute to poverty reduction and development. Educating children in a language they do not understand results in poor outcomes (cf. Romaine, 2015).

Thus, relying on foreign languages in education from the outset adversely affects learning. The reliance on foreign languages as languages of instruction negatively impacts literacy in both the local languages and the foreign languages. Not only do the people fail to gain literacy in their languages but they also discover that gaining proficiency in English is, for many including the teachers, a major challenge. Simango states it succinctly that "…relying on an unfamiliar language to disseminate knowledge has a number of disadvantages to start with. Not only do many learners fail to become literate in the target language, but also very few people, if any, learn and become functionally literate in their mother tongue" (Simango, 2015, p. 54). The language arts are, thus, instructive, in the necessity of devising and adopting culturally relevant pedagogy in, especially, STEM education, utilizing the local languages, especially in early childhood education. This restores social justice and observes rights in education (cf. Babaci-Wilhite, 2015).

Power Politics and STEM Education

Logic, science, and, especially, "mathematics (a field associated with intelligence)" (Nasir & McKinney de Royston, 2013, p. 276) routinely get equated with the profound thinking and reasoning that has contributed to material development and technological innovations central to modern or "civilized" society. It is significant to note that the view of intelligence that is hinted at here departs in important ways from that of other societies. Abubakar makes the claim that in Africa intelligence includes both cognitive and social responsibility. Citing Serpell (1993) Abubakar notes that in the earliest studies that describe the African concept of intelligence among the Chewa of Zambia, the concept is "understood in terms of four indigenous constructs: nzelu (wisdom) and chenjela (aptitude), which represent the cognitive aspects of intelligence; and tumikila (responsibility) and khulupilika (trustworthiness) which represent the social aspects" (Abubakar op. cit., p. 73). The intelligence that gets associated with aptitude for math is of a particular kind, given prominence in Western culture.

That said, math still gets accorded more of the culture-free knowledge than science in general. After all, the traditional view about math has been that "two twos are four, a negative number times a negative number gives a positive number, and all triangles have angles that add up to 180 degrees" (Bishop, 1990, p. 51). These statements are true the world over. They seem to have universal validity. Therefore, they must belong to a discipline that is free from the influence of any culture. However, Bishop points out that there is "no doubt that mathematical truths like those are universal. They are valid everywhere, because of their intentionally abstract and general nature" (ibid.).

The technical language and symbolic notations that characterize the study of math and science enhance the view of rationality and objectivity associated with STEM education, with detachment from ordinary language. In other words, in science and math there is special language devised for precision; technical vocabulary that, of necessity, involves abstractions and departure from ordinary language usage in order to reduce ambiguities or vagueness, considered rampant in ordinary language (cf. Chomsky, 1993; Ziman, 1978). However, this is not peculiar to STEM subjects. Technical or special jargon gets developed for occupations that require specialization, for example, specialized vocabulary in Swahili relating to maritime activities (cf. Mugane, 2015).

The abstractness in STEM subjects becomes a specialization of those initiated into the discipline, comprising the toolkit for the determination of "legitimate" agents of knowledge production and of "legitimate" knowledge. However, it is not value-free, being embedded in the value system of a particular cultural milieu, namely, that of white middle-class males that, in the name of objectivity and value-neutrality, can impose its ideology on society.

The idea of objectivity, as previously noted, is older than science and independent of it, being implicated in power politics of dominance and subjugation (cf. Feyerabend, 1987). Formal education has, in general, provided a convenient arena of power politics and political indoctrination. For instance, French colonialism, with its mission of assimilating Africans to French civilization, used education for the dominance and spread of the French language. Of a French education, Senegalese Governor General Chaudié had this to say in 1897:

> The school is the surest means of action by which a civilizing nation can transmit its ideas to people who are still primitive and by which it can raise them gradually to its own standards. In a word, the school is the supreme element of progress. It is also the most effective tool of propaganda for the French language that the Government can use (Crowder, 1962).

Thus, education during the colonial era, as echoed by the current President of the Republic of Malawi, Arthur Peter Mutharika, "…was an imperial weapon for domination"[7] serving the interests of dominant institutions or societies. These institutions normally deny "… the authenticity of other people's systems of knowledge" (Elliot, 2009, p. 285). As such, education in Africa retains curricula dominated by

[7] https://www.nyasatimes.com/mutharika-calls-education-revolution-africa-addresses-oxford-union/#comments.

the knowledge systems of those dominant groups. This is what Nobles (1986) called "conceptual incarceration." The term was used to designate "the state of imprisonment in European value and belief systems occasioned by ignorance of African and Native American philosophical, cultural and historical truths" (Hotep, 2003, p. 6).

Conceptual incarceration is accompanied by what Mugane has termed "linguistic incarceration." This refers to the nonuse of local languages in African education, where "the first language of the child is incarcerated, reducing education to the pursuit of fluency in English mediated by markedly non-proficient instructors. Whenever the switch is made from the child's first language to the language of the school there is always an instructional blackout. For the vast majority of children, the blackout is total and final. Learning is then reduced to verbatim memorization (and in numerous cases good hand writing)!" (Mugane, 2006, p. 14). Conceptual and linguistic incarceration in African education highlights the political nature of education (cf. Freire, 1970, 1998).

The view of the Senegalese Governor General Chaudié quoted above that education in Africa could be "the most effective tool of propaganda for the French language that the Government can use" (Crowder, 1962, op. cit.) was, later, emulated by Winston Churchill with regard to the globalization of the English language. Speaking at a momentous occasion when he was receiving an honorary doctorate at Harvard University on the September 6, 1943, Churchill stated[8]:

> I like to think of British and Americans moving about freely over each other's wide estates with hardly a sense of being foreigners to one another. *But I do not see why we should not try to spread our common language even more widely throughout the globe* and, without seeking selfish advantage over any, possess ourselves of this invaluable amenity and birthright…Let us go forward as with other matters and other measures …Such plans offer far better prizes than taking away other people's provinces or lands or grinding them down in exploitation. *The empires of the future are the empires of the mind* (emphasis added)

Phillipson (1992, 2009) noted that Winston Churchill was, at this occasion, effectively launching a global program to situate English as the indispensable language at the center of linguistic global governance after the Second World War. In other words, a creation of the new English-speaking "*Empire of the mind*" with the British and the American in insidious control globally. While history, particularly African history, has recorded how colonial domination exported the English language to the African shores in the 1950s and 1960s, a recent British Council report (Graddol, 2010) demonstrates further how this Churchillian program is still sustained through slow endemic infusion at multiple levels and continues to maintain high status (cf. Khumalo, 2016).

Math and science education have played a significant role in the subjugation of erstwhile colonized nations. The content of, and rationality associated with, these subjects was deemed to lie beyond the cognitive and linguistic capabilities of the colonized and, largely, nonwhite races. In reality, this had to do with politics of domination and subjugation. Feyerabend noted that it is true "…that Western science now reigns

[8] I am indebted to Langa Khumalo for drawing my attention to this Sir Winston Churchill's statement made at Harvard.

supreme all over; however, the reason was not insight in its 'inherent rationality' but power play (the colonizing nations imposed their way of living) and the need for weapons. Western science so far has created the most efficient instruments of death" (Feyerabend, 1988, p. 3) Ochieng'-Odhiambo observed that "Western philosophers had been skeptical about the existence, if not certain of the absence, of rationality and reflective thought in African minds" (Ochieng'-Odhiambo, 2010, p. 9). According to the perpetrated myth, African languages are incapable of facilitating "rationality" or "reflective thought" that is central to philosophy and to math and science. This contributed significantly to the conceptual and linguistic incarceration of African education.

The alleged lack of expressivity of African languages is a view that lacks empirical basis. The belief derives from racist assumptions about the inferiority of African languages and cultural values or the presumed nonexistence of AIKS. It is fostered by the traditional Eurocentric orientation of the educational curricula in Africa that focuses on the cultural and scientific practices of the former colonial masters. The myth of the inferiority of African languages is simply that, a myth, rooted in the legacy of colonialism and the ideology of inferiority of African culture and knowledge systems. As pointed out by Brock-Utne "it is difficult to understand where the belief that science is better learnt in English than in other languages originates. While it is a belief one often comes across in Africa, the claim seems so unsubstantiated" (Brock-Utne, 2012, p. 9).[9]

With math, its role in power and elitism can, apparently, be traced back over 2300 years ago, to Plato's *The Republic*. Stinson noted that in the fictitious dialogue between Socrates and Glaucon regarding education, "Plato argued that mathematics was "virtually the first thing everyone has to learn…common to all arts, science, and forms of thought." Although Plato believed that all students needed to learn arithmetic—"the trivial business of being able to identify one, two, and three" (page reference omitted)—he reserved advanced mathematics for those that would serve as philosopher guardians of the city" (Stinson, 2004, p. 9). Thus, Western mathematics comprises one of the most powerful weapons in the imposition of Western culture and for the empowerment of the elite. STEM education in general, but math in particular, has been exploited to (re)produce and regulate racial, ethnic, gender, and class divisions, becoming a gatekeeper. The agents of knowledge production, and the children who belong to their culture and linguistic heritage, get empowered to reach the top echelons of the class divisions in the stratified society. It is not surprising that in the culture border crossing from the everyday lifeworld of the child to the culture of science, the "potential scientist" whose transition is smooth gets facilitated because "the cultures of family and science are congruent" (Jegede & Aikenhead, op. cit., p. 50).

[9]William Kamkwamba dropped out of school in Malawi during his early teens because of lack of funding. Yet, using local resources, he proceeded to build a windmill in his village in Kasungu district that generated electricity to his house. His accomplishments got recorded in the *New York Times* best seller, *The Boy Who Harnessed the Wind. Creating Currents of Electricity and Hope*, NY: Harper Perennial. Significantly, the scientific knowledge and the technical expertise did not depend on proficiency in English. At the time, he hardly spoke the language.

Conclusion

In the cultural invasion that characterized colonialism, education was a crucial component. It played "…a critical role in promoting western mathematical ideas and, thereby, western culture. In most colonial societies, the imposed education functioned at two levels, mirroring what existed in the European country concerned…[and]…in some of the mission schools and in the later years of colonialism when elementary schooling began to be taken more seriously, it was, of course, the European content which dominated" (Bishop, 1990, p. 55). While STEM education is, indeed desirable as a significant component of "global" and technical knowledge, within the context of African education, it has played a pivotal role in the retention of Western values in African education and the cultural domination that goes with that.

Mathematics and science can still make connections with the indigenous culture and environment, becoming relevant to the needs of the indigenous society. This is achievable if the culturally relevant knowledge and the languages in which that knowledge is represented and expressed get incorporated into the educational program. Language arts embody knowledge that is of relevance not only to concepts in STEM education but also to other aspects of growth and development. It is represented and imparted in local languages. Children's play songs, games, drama, storytelling, society's various strategies of encoding and imparting critical and crucial knowledge and wisdom, such as proverbs and other language arts, constitute culturally relevant knowledge. Abubakar argues that the incorporation of African oral traditions in the educational process "…fosters cultural identity, even as Africans move forward. A well-known Swahili maxim warns: 'mwacha asili ni mtumwa' (he who discards his traditions and culture is a slave); an obvious potent reminder to Africans not to lose their cultural heritages. Africa should learn from their cultural heritages while enhancing them within the school system and other channels of purposeful cultural recreations" (Abubakar op. cit., p. 74). This can provide a bridge from the local knowledge base to the acquisition of knowledge that comprises 'global education' including STEM education, delivered eventually in foreign languages. In brief, language arts play a crucial role in promoting success in formal education.

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Chapter 3
Educating For/Against Modernity, Arts and Technoculture

Purushottama Bilimoria

Abstract The chapter undertakes to tread the tenuous ground between modernity and the post-modern which has reverberated with debate in the second half of the twentieth century when both the theoretical framework and the political hegemony of the Western European tradition began to be challenged. This is achieved basically through an analysis of three issues of comparative concern between three as it were avatars of after-modernity engaged in this critical debate: Gandhi (in South Africa/Asia), Lyotard (in France) and Habermas (of the Frankfurt School, Germany); (i) the role of the intellectual in the critique of the project of modernity's universality; (ii) via the intellectual and intelligentsia, the pragmatics of de-conditioning the ruse of tradition, the sway of the Enlightenment, re-educating ṛta (*dharma*, morality); and (iii) questioning the excesses of modernity's hand-made culture of technology. Eager to critique modernity, each protagonist in our inquiry seems to backtrack a little, either as a critical apologist for modernity, albeit unfinished (Habermas), deconstruct and rein in on after-modernity but without an interventionist pragmatics (Lyotard), or mildly dissimulate but actually shame modernity in an anti-Empire challenge (Gandhi). The strands here bespeak *differend* approaches in each to the question of education, interpreting discourse, its violence, and aesthetics. Yet the project of modernity remains un-'liquidated' in as much as the capitalist technoscience and globalization foreclose education in the arts. Eager to critique modernity, each protagonist in our inquiry seems to backtrack a little, either as a critical apologist for modernity, albeit unfinished (Habermas), deconstruct and rein in on after-modernity but without an interventionist pragmatics (Lyotard), or mildly dissimulate but actually shame modernity in an anti-Empire challenge (Gandhi). The strands here bespeak differend approaches in each to the question of education, interpreting discourse, its violence, and aesthetics. Yet the

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Introduction

The chapter undertakes to tread the tenuous ground between modernity and the postmodern which has reverberated with debate in the second half of the twentieth century when both the theoretical framework and the political hegemony of the Western European tradition began to be challenged. This is achieved basically through an analysis of three issues of comparative concern between three as it were avatars of after-modernity engaged in this critical debate on language and human rights: Gandhi (in South Africa/Asia), Lyotard (in France) and Habermas (of the Frankfurt School, Germany); (i) the role of the intellectual in the critique of the project of modernity’s universality; (ii) via the intellectual and intelligentsia, the pragmatics of de-conditioning the ruse of tradition, the sway of the Enlightenment, re-educating *ṛta* (*dharma*, morality); and (iii) questioning the excesses of modernity’s handmade culture of technology vis-à-vis STEAM, wherein there is a wholesome embrace of the arts.

The imperative of this comparison suggestively emerges by dint of the recurrence of the trope of ‘avatar’ in Lyotard’s writings (*Libidinal Economy EL* 22, 31) and in commentaries thereof (a curious reversal, it would seem, of the Judeo-Christian messianic-*incarnatio*), and again in the encounter of his works on the postmodern. One finds a resonance here with Gandhi’s philosophy of education interspersed with his comments on the *avatar* model presented by Krishna in the *Bhagavad Gita*. It is also echoed in Gandhi’s identification with the messianic projections of the *avataric* epiphany that earned him the title of the ‘Mahatma’. The question arises as to what it would be like to interlope these didactic reflections with Habermas’ voluminous tomes on modernity’s interests and ethics. Since Lyotard directly confronts Habermas’ critique of modernity and within this treatment the latter’s suggestive ideals of education, it behoves us to ponder where exactly would or does Gandhi’s ideas of education in the broader backdrop of his own variant critique of modernity would fit in. Now, all three *avataric icons* in their own right, to be sure, seem to begin with a zeal to offer radical critiques of modernity; but each seems to hold back just a little, as a critically unmitigated apologist for modernity, albeit in its unfinished/‘incomplete’ form (*a la* Habermas), and move towards ‘after-modernity’ but without an interventionist pragmatics (as in the case of Lyotard). Or alternatively, one engages in mild deconstruction but sets out to shame modernity in an anti-Empire challenge (which we have with Gandhi). The claim in this chapter is that all three great thinkers falter on their own peculiar way, to destabilize modernity in as much as they skirt around the ambiguity inherent in the qualifying prefix: ‘*post*-’. The aim here is to demonstrate this wider claim in respect of a much narrower concern by comparing their views on this matter. In so far as their stance on educating against technoculture is concerned, it seems clear that the comparison holds. The three different strands here, in respect of the *differend,* hone in on a somewhat similar target. However, they also take disarmingly variant approaches—to the question of education against technoculture, interpreting discourse and its violence, and aesthetics. Hence, the goal will be much more restricted for the present purposes, dealing here only with education—and that too in relation specifically to technoculture—in respect particularly of the role of the intellectual in the programmatic towards the question of correcting modernity's path to Enlightenment.

The icon of the modern *intellectual* was born around the same time in France and in the subcontinent—the end of nineteenth century, during the Dreyfus affair and the Muslim resistance to imported British scientism in India, respectively. The insipient movement was fanned by recourse to public petitions, letters, journals, printing press, across the board (Zola in Paris and Gandhi in Johannesburg). Influenced not least by the damning critiques in the works of Emerson, Ruskin, and Tolstoy (with whom Gandhi corresponded), the young Gandhi bypasses or escapes the allure of the Enlightenment, even as he both anticipates and precipitates a greater 'avataric' role for the intellectual in the public moral sphere. While in South Africa/Natal, the fledgling attorney-turned social activist set out to experiment with alternative models of schooling, close to the kibutz-style communes (which he christened 'Tolstoy' and 'Phoenix Farm' ashrams). The lifestyle featured craft workshops, non-violence training camps—underscoring the dharmic commitment to a non-injury and holding on to truth as justice that was to become a political strategy for championing compromised (or withheld) rights of oppressed or subaltern communities. The spiritual life at the 'ashrams' was also rather strict and pursued with a degree of stoical dedication. From this base and field of strength, Gandhi and his ardent disciples were able to wager non-cooperative protests and *satyāgraha* resistance against imperial–colonial excesses in South Africa. Later on, this method of non-violent resistance protest (which Gandhi distinguished from Tolstoy's passive non-resistance or pacificism) was continued in much more organized and successful forms in British India that launched the freedom movement and arguably eventually clinched Indian Independence—but ironically also the subcontinent's partition that saw the birth of Pakistan—in 1947. This discussion will be developed in Part II. We turn presently to the second avataric icon—François Lyotard.

Up until 1969, while a *lycée* professor in Algeria, Lyotard became embroiled in the Algerian question and threw his support behind Algeria's struggle against French colonialism. He was also involved in political actions at Nanterre University. However, in the 1970s and since, Lyotard took the Socratic turn, and in the manner of Voltaire, perhaps also Nietzsche, embarked on critical writing and pushing for *puissance* on the edges of modernity's near collapse through contradictions inherent within its own *discours*. But he did not make a complete commitment to any sort of *Programm* and/or enlisting of religious interests in the political sphere—even for its *jouissance.* Mahatma Gandhi, on the other hand, is astutely pragmatic and a 'doer': he becomes a bedfellow with anti-deluvian revolutionaries (he has to be sheltered from General Smut's brutal police) and carries out plans for the disruption of a non-theosophic modernity (through dissemination of his message on postcards and in print journals that are now part of the 130-volume *Collected Works of Mahatma Gandhi*, e-CWMG). He, so to speak, dirties both hands (more so later in India, with khadi and salt as symbols of anti-colonial protest, the second of which becomes the trigger, literally, for General Dwyer-led India's 'mini-Auschwitz', famously known as the Amritsar Jallianwala Bagh massacre of 1927). At the same time, the people's saint continues to develop a Dewey-Montaguean pragmatics for what he calls a pedagogy in 'Basic Education' (*Nai Talim*), which, as a manifesto for a child's right to education as a basic capability gained through regional medium, remains poignantly relevant for the developing world even as it emerges from a long period of traditional slumber and colonial oppression.

Yet the project of modernity remains un-'liquidated'; the capitalist technoscience (Habermasian 'state of reason') and globalization (universality's alter-nationalism) stride ahead to complete the project. Lyotard's critique of the malaise and the failure here of education since at least the Enlightenment (vis-à-vis, say, the Augustinian model) turns largely on the universality of *language*, the ruse of meta-/grand narratives, the dissimulation of the arts along with the de-aestheticization of the sublime, and the West having lost sight of the pedeia of *Bildung* (training, or better, educating) that builds around pedagogy and *reform* in its unchecked and unrequited march towards the technoculture of arid science.

Part I: Gandhi's Idea of Basic Education

'Mr Gandhi, what do you think of Western civilization?' Gandhi: 'I think it will be a jolly good idea'. This cryptic response, despite his English education—he was called to the Bar at the Temple Inn, in London—sums up rather poignantly Gandhi's diffidence towards the promises and wherewithal of the West, on the coattails of the Enlightenment, to deliver a 'civilization' worth its name. Echoing here, not a very different caution that Heidegger prosaically reminded the East of, *against* the grain of Husserl's prescription of the inevitable 'Europeanization of the world'. Yet Gandhi betrayed a certain ambivalence towards, on the one hand, the pre-modern traditional frameworks in which much of the Indian society continued to eke out its living, and, on the other hand, the contours of modernity that had arrived at the doorsteps of the non-Western world (Bilimoria, 1993a, pp. 128, 133). Although Gandhi's political pragmatism draws heavily on the resources, capabilities and the mobilization of the collective, his humanism is based firmly on the integrity of the individual who is the bearer of basic human rights, including the capability of language: 'The individual is the one supreme consideration'; '[I]f the individual ceases to count, what is left of society?' (Bilimoria, 1993a, p. 140; Gier, 2004, p. 12)[1] It is however not the collective, in the sense of the community and the local, or even the 'mob and herd mentality', that he seeks to question, but rather the apparatus of the *state* which he believes destroys individuality, so essential to progress. Hence, his 'experiments with truth are distinctly modernist with their firm assumption that the individual is the final arbiter

[1]Gier is citing Jayantanuja, p. 72, and *Harijan* 9, Feb 1, 1942, p. 27.

of action'. (Gier, 2004, p. 12). In rejecting also the pre-modern cyclical view of history in favour of a modernist view of linear moral progression, Gandhi makes this very modernist assertion: 'The force of spirit is ever progressive and endless… The remedy [from self-destruction] lies in every individual training himself for self-expression in every walk of life, irrespective of response of the neighbours.' (Gier, 2004, p. 13, no. 18). Gier comments that this is not only progressive and individualistic, it also appears to undermine his pre-modern view that one should train in the profession of one's father. And here one might think that Gandhi is prepared to overturn the centuries-old caste system, as Marx would the class system in the industrial society, on its head. Yes, and No. While he rejects the rigid hierarchical arrangement of orthodox's caste predilections, he stays with the more vertical distributive, functional and performative idea of a reformed caste grouping on the analogy of the living organism with its feet, hands, belly and the brain, no member of which singly should be seen as superior to the other, despite transcendentalist Vedānta and Descartes's *persona machina* ontology; otherwise, there would be serious dysfunction and the actual practice of *ahiṃsā* would not be possible. People go through different stages of self-development and modes of life; some people are suited to one set of tasks, while others are to other tasks, a little like Plato's ideal society based on stations of life divisions.

But one strong element that creeps into Gandhi's conservatism on this score is nevertheless the egalitarianism of social liberalism which would be intolerant of the idea of untouchability, and this Gandhi sought to rid the Indian society of as much as possible. Each person, he would say, in the interest of communal self-sufficiency, or *swadeshi*, should be prepared to perform the lowest kinds of menial labour, down to cleaning one's own toilet, in deference to those who we have exploited for centuries in these roles (Gier, 2004, p. 128). And the same with religions of others: one should not merely show tolerance towards the faiths and rites of others, but actually partake of their precepts and forms of life. Whatever the shortcomings of Gandhi's reformed caste structure, one thing is clear: he would not have a community of people be reduced to the numeral fragments of social atomism of classical liberalism and utilitarianism, with reinforcements from the 'survival of the fittest' rhetoric of social Darwinism, or to strings of social security numbers at the behest and control of the state. His anarchism had a quaint logic that even ardent voices from within the Dalit community and more extreme anti-caste reformists had failed to appreciate: they took him to be a traditional apologist, while Gandhi's larger vision was to avoid the replacement of caste with an equally destructive class structure, which then modernist Marxist babus would set about destroying (the overlaps, of course, notwithstanding as both caste and class have controlling intrinsic socio-economic interests in their formations). Social atomism eventually falls prey to the hands or machinations of the larger corporate power we call the centralized state, or the Machiavellian *politibo*, democratic or of *res-publica*, or some other utopian—craft, while a more organic and loosely federated body of individuals who owe their citizenship as much as their livelihood to a self-regulated, self-sufficient decentralized and local governance or village republicanism (called *panchayati* and *Ramrajya*) provides better, in the long run, for the equality and integrity of all souls—which echoes a process philosophy politics and Gier's constructive postmodern preface to the new Thoreauan 'enlightened anarchism'. But in the view of some, like Terchek, Gandhi's anarchism is modernist, because it is also utopian and is based on the ideal of moral autonomy, in the Euro-American liberal tradition. This cannot be sustained, as the other essential elements of modern utopianism—viz. nationalism, militarism and prelapsarian control over the natural environment—are patently absent in Gandhi's *Ramrajya* (Prabhu & Bilimoria, 2017). That very form of instrumental, calculative reason that we shall see Habermas professing in a systematic ordering of society is not the conscience of Gandhi's individual who, at will, could decide to mount an act of civil disobedience against bureaucratic threats or infringement of collective rights, without necessarily waiting for communicative or discourse ethics to have done its work, behind as it were the veil of abstractions, or igno*rant*ing against the others. Of course, Gandhi had a more classical idea of the *rights* discourse, wherein an entitlement in the possession or birthright to one individual was not to be eroded or threatened by another individual, much less by the state; further, every right entailed a duty on the part of another or some agency to respect that right (Bilimoria, 1993b, 1993c, p. 12). Thus, if a child is deemed to have a right to language as a medium of communication and instruction, then the parents and the state have the duty to provide the wherewithal for the realization of this basic capability. And by collective rights, we mean the entitlement such as that of self-sovereignty of a group, or the entitlement of a traditional tribe to (its belongingness to) the land, or of a nation's right not to be threatened or attacked by its neighbouring nation (Bilimoria, 2002). Where world governance is formed out of federations of village republics as a decentred polity (*prajā)* with certain 'national boundaries', to be sure, for which Gandhi used the pre-modern term, 'country', is not the same as a 'nation of individuals merely held together by state power (*rashtra*), what we call 'nation-state', the militarized, political entity that looks upon its neighbour as an enemy and a threat (Anthony Parel cited in Gier, 2004, p. 15); hence, he rejected the British-carved map of India, preferring the more ancient landmarks that included parts of what are now Afghanistan and Pakistan to the west and Bangladesh and Burma (Myanmar) to the east.

Gandhi had already voiced concerns about the limits of liberal democracy as well, for this political system in his view does not empower individuals; 'rather', as Parkeh so aptly phrase it, they abstract 'power from the people, concentrate it in the state and then return it to them in their new [abstract roles] as citizens' (Gier, 2004, p. 15). While *satyāgraha* and *swadeshi,* which Gandhi outlined in his little book on *Hindswaraj* as he sailed from London to South Africa, empower the individual—read *manusya*, human subjects,—to work non-violently for the common good, as if one's self was the person of the other. Ironically, the book owes its inspiration to European thinkers, or its leftovers, Socrates, Tolstoy, Ruskin and Thoreau, who were not out to destroy or reduce Western civilization to the rubbles, but to heal it and regain the lost moral ground (Gier, 2004 p. 18). But these presentiments echoed welcome synchronicities in the Vaishnava ears of Gandhi, who was not brought up in the orthodox priestly temples of orthodox Vedic ritualism or even the non-dualist-Vedāntic metaphysics, much less Nyāya logic. So he valued ideals of Hindu *dharma, karma* and (as we saw) a muted caste arrangement, but only if these measure up to the standards of modern legal and liberal egalitarian ideals as well (he had Rousseau in mind and Thomas Payne's 1791 classic, *The Rights of Man)*. He situates himself in a space we might call the middle politics of non-modernity (not so much anti-modernity, nor entirely an apologist or the pre-modern or fast-forwarding the post-colonial).

An Education Project to Reflect on

On the educational side now, Gandhi and his contemporaries are of course confronting an Orientalist project in pedagogy. This project began with the East India Company's design to rid India of its arcane learning system, which would with the help of Christian missionaries replace the frivolity of Hindu and Mohammedan literature with the more salvific and at once utilitarian textures of the West. The project was continued by several Orientalists who were scholars of Sanskrit, Arabic and Urdu, and some were also servants of the East India Company or were in prominent administrative positions. The Orientalists did not believe that the natives were capable of skills in the classical languages and texts, which were more like fossils of interest to archaeologists and philologists. A prominent Orientalist, H. H. Wilson, even felt that the natives were not deserving to learn English (Rao, 2016, p. 3). Hence, language as a basic human right and a capability remained annulled for the native population. So if they are not to learn the vernaculars and are excluded from English, what kind of learning and pedagogy are the natives deserving or capable of? Yet others were more benign and felt that education as a reformative movement across the nation was essential to bring about needed changes in the Indian society. James Mill (father of John Stuart Mill, who also worked for the East India Company) was confident that these reforms would suture and transform the whole of Indian society, and set it 'on a rapid advance up the scale of civilization'. (Ghose, 1970, p. 110). But it was the (in)famous Minute on Education of 1835 issued by Lord Macaulay (born Thomas Babington, 1880–1859) that had set the agenda of eroding traditional Indian learning of the hitherto guru–disciple kind where instructions were in the language of the region and in the cultural ambience of the community, its long tradition of classical systems of thoughts and *dharmanītī* or governance, and all that might today come under the arts and law. The mooted erosion would also wittingly impact on the alleged perfidious Sanskritic and Arabic babblings and mystical twaddle, indeed by a sweeping introduction of the English literature and European law across the board, with the result that, as Macaulay professed, 'a class of persons, Indian in blood and colour, but English in taste, in opinions, in morals, and in intellect…' would be inducted into a totalizing European learning and abducted away from paganist idolatry (Young, 1952, p. 118). The introduction of the great literary classics of the Greeks and Romans, the 'hard' sciences, mathematics, moral philosophy, reminiscent of STEM as studied in the learned seats of Cambridge and Oxford, would wash away millennia of this distastefully impoverished culture of the inhabitants. That was the project of modernity, for the subcontinent at least, but was applicable to the colonies across Africa, Oceania, the West Indies and South America as well. It is tantamount to a wholesale erosion of a communitarian right to language, culture and the arts.

Thus hand in hand with a critique of modernity comes of course Gandhi's qualms about the pedagogy that trains or schools a child—not insufficiently as for Habermas—but rather excessively (as we shall see, a complaint shared by Lyotard as well) in the instrumentalist automations of a science-laden technoculture. Let us see Gandhi on this.

A Science-Laden Technoculture

On a visit to Bangalore in 1927 when he expressed concerns for villagers exposed to modern scientific practices, Gandhi asked the Indian Institute of Science: 'How will you infect the people of the villages with your scientific knowledge? Are you then learning science in terms of the villages and will you be so handy and so practical that the knowledge that you derive in a college so magnificently put and I believe so magnificently equipped—you will be able to benefit the villagers?' (Kumar, 2000, p. 246). His question is directed at the sufficiency or a certain lack in respect of STEM.

Gandhi's views on science might have seemed frustratingly conservative at the turn of the twentieth century, a time of simmering preoccupation with ending British dominance in the colonized world. Amid the rush for self-sufficiency, any caution to ensure rational and sympathetic integration of modernity and tradition appeared to simply entail a deceleration of the coveted outcome. While science was undoubtedly a powerful instrument of the Empire, which Gyan Prakash explores in *Another Reason: Science and the Imagination of Modern India* (1999) as a hybrid form intertwined with indigenous forms of knowledge, it did not serve well as an instrument of nationalism because it underpinned a more universalist message and would eventually integrate all people into an amorphous identity at the global level in the name of liberalism and globalization. Nevertheless, there were educationists like Sir Sayyed Ahmad Khan and scientists like Jagdish Chandra Bose who were committed to a patriotic project of taking India to the frontiers of its own discoveries, past with present.

However, Gandhi's initial attack on Western modes of education was not quite on the preponderance of scientific learning as was his preoccupation with the abstractness, obtuseness and emphasis on a curriculum that seemed geared towards creating a bureaucratic civil service culture, on the one hand, and mass labour and middle class platforms that were simply to be fodders for the industrial and commercial machinery (Gandhi 1946, 1950). Such educational platforms seemed ill-equipped to engender a culture of self-development, linguistic capabilities and grounding in the arts, perhaps also law; nor towards empowering self-sufficiency training in all aspects of enlightened education—from crafting one's own sandals to appreciating the aesthetically sublime (via religious and devotional imaginary) (Bilimoria, 1993a; Gandhi 1938, 1953, 1962).

On the psychological side, again, an overemphasis on the cognitive rational development masked the nurturing of the more basic conative, affective and spiritual—including the embodied mental—terrains in the child. The appropriate context of such a training for him was not necessarily the classroom, or the institutionalized school—but rather the *ashram*, a quasi-monastic commune-itarian arrangement where pupils, from their very formative years, encounter and live through the challenges of social realities and learn thereby the principles and virtues or values by which such processes are morally and soulfully handled. The elders and intellectual guides and leaders set the example and spend time erecting houses, taking classes for the pupils, *and* participating in *satyagraha* or 'soul-force' activism in the towns and elsewhere: these experiments with truth as he called them constitute a package that we might call 'education as the *political*'—i.e. education as a right and an instrument or vehicle for political reform and action, even resistance—which Gandhi signposted in the communes, he called Tolstoy Farm and Phoenix, respectively. As a reconstructive, only-just modernist, post-colonial, Gandhi (1946, 1953) connects the virtues of the Socratic *daimon*—of moral courage, aesthetic, arts, etc.,—and Aristotle's *phronesis* (which he gets from Montague, but also Rousseau, Montessori, and later on Dewey) (Ramana Murti, 1970, pp. 66–81) with Christian *logos* of self-suffering. But he also draws on Indian religious (almost tāntric) virtues of duty, virility, tolerance, forbearance, justice, compassion, non-retaliatory truth-making, non-injury, fasting, etc., to articulate a revolutionary psycho-spiritual empowering *technē* (or, the after its impact on the African American Civil Rights Movement, the 'Soul-power', the 'Power to Truth'; or to prosaic New Yorkers, simply 'The Yoga') (Bilimoria, 2013).

As I have just hinted, Dewey's philosophy of education had an impact on Gandhi; Dewey was in turn influenced by Josiah Royce's moral teaching of inclusive community, where an individual's life and willed actions are morally significant if it has as its *telos* a cause and that too for the 'furtherance of loyalty in my fellows' (Royce, 1995, p. 56). Loyalties may be multiple; but it is a *loyalty to loyalty* that is the essential developmental cause. The techniques and effective pedagogy are means to that end. Thus, this regenerative *technē* of casting a *megalopsychia* (Aristotle's 'great soul') is not an end in itself, but rather a means—*pramāṇa* or effective measure—for the good of all: in Sanskrit, *lokasaṃgraha*, or *sarvodaya.* One might be inclined to suggest that Gandhi here slips into the modernist trappings of utilitarianism by professing a 'greater good for the greater number' principle, but recall that the means is not an instrumentalist, cold or virtue-less, calculative expenditure of talents merely for the greater end in some objective performance, by force of culture or the law, or a deposit in the bank vault. Rather, like Aristotle's *eudemonia* principle and the Bodhisatva's meritorious Buddha mind, the means are also moral *ends* in themselves—*technē tou biou*,[2] and the *aletheia* of inner moral–spiritual accomplishments of the person, as a work of art, constitute in sum or cumulatively the greater good or social weal: an organic vision of socialism, if you will, is the operative motif here. But others as *the*

[2] Gier (2004) invokes Aristotle and Greek terms and links it to Foucault's care of the self, *logos,* art, ethics, aesthetics.

non-other is always, for Gandhi as it was for Rabindranath Tagore, the spiritual and aesthetic end, *dharma* that is, or the ethics of being (Gandhi 1945). This sentiment is echoed in Castoriadis's contention that education involves 'becoming conscious that the *polis* is also oneself and that its fate also depends upon one's mind, behaviour, and decisions; in other words, it is participation in political life' (Castoriadis, 1991, p. 101).

The Nobel laureate, Tagore's critique of Gandhi, we might note in passing, is a paltry academic response,[3] for Gandhi had visions of the right to free education for all children up to the elementary level. This was before any conventions underwriting education as a fundamental human right had been articulated; but Gandhi had the intuition, as did indeed Tagore, that education is a birthright of every newborn as he or she grows into adulthood (Gandhi 1962). This was written into India's Constitution in 1950, where Article 45 specifically directed the state to endeavour to provide free elementary education for all children up to the age of 14 by the year 1960. This of course entailed the right to study one's native language and possibly be instructed in that language also. Unfortunately, this was a non-judiciable (directive) principle, and it was not until 1993 that the Supreme Court of India declared education a justiciable fundamental right for all children up to the age of 14. But a bill to enforce the provisions (albeit from age 6–14) tabled in 1997 fell with the change of government of the day, and it has never been revived. The problem is as much quantitative and accessibility as it is qualitative.

In summing up Gandhi then, his vision of education does not begin with the three 'Rs': Arithmetic, readings, and writing, with an increasing slant in the modernist faith towards the sciences, or not merely with these, but rather with an integration of the body, heart, passions, the mind and intellect in a context of training that recognizes the wholeness, not the duality, of the Cartesian mind and the art–aesthetic–athletic body: the body both thinks and does, the mind only reasons, which is but one function of the *psyche*-: 'By education I mean an all-round drawing out of the best in [the] child and [hu]man—body and mind and spirit' (Bilimoria, 1993a; Gandhi, 1937, p. 234, 1938). However, preferred 'learning through doing' and hence the emphasis on what has mistakenly been taken to be a lop-sided emphasis on vocational training (for which he was questioned nevertheless with a degree of empathy by his friend by Rabindranath Tagore, the Indian Nobel laureate) in what Mahatma Gandhi outlined as his programmatic for Basic Education (at the now legendary All India National Educational Conference held in Wardha, on 22 October 1937) (Gandhi 1948). Incidentally, Gandhi's educational philosophy has had an immense impact in a couple of sub-Saharan African countries, Botswana and Zimbabwe, and the Kibutz of Israel, while in, except for pockets of surviving Gandhian schools in Wardha and northern Gujarat regions, most are being corrupted by the rise of a strident Hindu bourgeois fundamentalism. But what Gandhi is really proposing, for us here and posterity, is the forging of the educated as the activist, intellectual, the political zoon, with a foot each in tradition and modernity, but shaking (not forsaking necessarily) both to the core, and confronting them in a deconstructive dialogue, so that *truth* (not just

[3]See, Bindu (2015), Prabhu and Kelekar (1961).

language, Speech, as Heidegger was thinking around the same time) would speak and indeed act in earnestness.

Part II Habermas and Modernity's Project

Let me now briefly come to Habermas. If Gandhi is highly critical, Habermas is an apologist for the 'project of modernity' and, in the fashion of the Frankfurt School, argues rather that every attempt should be made to preserve the 'emancipatory impulse' behind the Enlightenment (Bilimoria, 2014). Modernization in the post-industrial society might well take a different direction, but its praxis should not be based on performativity, or the idleness of pure aesthetics: 'the dionysiac force of the poetical' (Habermas, 1981, p. 13). The failure of modernity—if indeed *failure* at all—for Habermas is rooted in 'the splintering off of totality of life or unity of experience into 'pluralisation of diverging universes of discourse' that has shattered the naïve consensus'. (Habermas, 1985, p. 196; Peters, 1995, p. 36). And consensual knowledge is what science is based on, as is the programmatic for communicative rationality that sets aside absolutes and totalizing theories, including that of Western logocentricism (Ibid). This is the rational basis of action. Still, Habermas is critical of performativity (the plotted efficiency criterion), which inculcates training for the sake merely of technical and productive ends. Even his 'consensual' premise, particularly for the educational dimension of science, takes second seat to *paralogism*, i.e. the search for 'instabilities' and undermining of what is taken to be 'normal science', particularly in the age of high technology, and in the background of the critique of all ideology (Habermas, 1996, pp. 84–85). The iron cage caricature of rationality that Marx and Weber painted is just too narrow and overdetermined in the interest of class politics or bureaucratic and technocratic rationalism, while the normative and 'affective' areas of thought are effaced from the more value-and-interest nuanced presupposition of rationality. There has been an unmitigated bifurcation of reason into the instrumental (positivistic) and moral–practical form, the twains seem never to meet in a unitary praxis of the total development of the individual. Hence, his critique of the positivistic and empirical 'knows all' self-assuredness of science and paradoxically the technological means/end form of practice—properly speaking *instrumentalist mentalité*—of late Western capitalism. Education or pedagogy in the modern times has become something of a captive to this ruse of technocratic rationality (Marshall, 1995, pp. 178–180). These are two significant signs of moderation in Habermas's otherwise more universalistic and quasi-Kantian ecco humanism, with which indeed Lyotard finds himself to be in some agreement as he develops his own critique of the differend. But the agreement between the two theorists does not run that deep (in fact, it barely crosses the Rhine), especially since Habermas has already pre-empted his criticism of Lyotard by including all French post-structuralists and philosophers—the 'young conservatives' as he calls them. He deems them to have fallen under the relativist snare of 'postmodernism', for which he singles out Foucault as the gang leader, followed by Derrida, Deleuze; by 1984, he targets his critique more pointedly at Lyotard himself (Habermas, 1981).

The question for Habermas, that Lyotard also poses, is the 'how' of this unitary praxis? On the one hand, Habermas seems committed to the value orientation of education, while on the other hand, the preferred means for this realization of values need not to be so compellingly bereft of the 'efficiency' and 'economy' of the procedures, normatively, being formulated in the technical spheres, he means particularly science, provided they do not form part of the definition of rationality (which technological rationality indeed takes it to be so, but mistakenly (Habermas, 1996, pp. 86–87). The preferred operational *vivendi* is for a dialectical relation between values and techniques for their satisfaction. He invokes Dewey for having had this insight into the interconnection of values with technical knowledge; techniques are multiplied and improved, while values subject themselves 'indirectly to a pragmatic test of their validity'. In a more general way, Gandhi had not ruled out the role of technical knowledge, particularly in respect of the vocational orientation—the hand-ever-in-action—that he articulated in his Basic Education schema. However, two points of contrasts stand out: (i) Gandhi did not as Habermas is bent upon encompassing the dialectical stratagem under the transcendentalism of reason, and (ii) the values in the end outweigh the means, the pragmaticism to be sure, of technical knowledge, which Habermas would fain have us believe can be seen on a par with, say, Aristotle idea of intellectual wisdom as an end in itself. In that regard, Tagore's criticism of Gandhi rubs off on Habermas as well: 'the birds do spend their whole day foraging for food; they tweet, sing melodies, fly in joy, and play with their own kind'. There is little evidence in Habermas that despite his concerns for the role of values in the modes of knowledge-making and its transmission process, in more concrete terms they scarcely echo a gradual march towards the rich legacy of European aesthetics, of play, of leisure, let alone the excelsus of the Kantian sublime, the Spirit. Gandhi is not faultless here either, but his technical pedagogy and the political encompassed the spiritual and aesthetic in some 'lite' sense as well.

Part III: Lyotard and the Postmodern Conditioning

Lyotard, in contrast to both, but especially Habermas, is deeply suspicious of the promises of the 'Enlightenment', even the so-called radical enlightenment, which is a legacy of the seventeenth–eighteenth-century Italian renaissance and German neo-idealism that Habermas believes is still simply 'incomplete' and not deficient as a universal project as such (Habermas, 1987). To Lyotard, the project of modernity 'has not been forsaken or forgotten but destroyed, 'liquidated'' (Lyotard, 1992, p. 30) and this 'destruction' is nowhere more marked than in the symbol of 'Auschwitz' and the 'victory of capitalist technoscience over the other candidates for the universal finality of human history', for neither have succeeded in 'completing' the project, but rather capitulated it by dint of its own inherent contradictions. It is facts—'[T]he subject's mastery over objects'—that contemporary science and technology generate that brings not ‘greater freedom, more public education or greater wealth more evenly distributed. It brings an increased reliance on facts’. Certain modes of narration are more worthy than supposed hankering after ‘objective theory’, which is on a par with meta- or grand narratives. Technoscience still believes it will fulfil the project of modernity, meanwhile it continues to subjugate nature (which includes also the human subject, its body, language and genetic codes). The subject—recall the ‘person’ in Gandhi’s vision—has all but been lost in the, as it were, manu*fact*ured process. The manufacturing of facts, the *known and named thing,* (Lyotard, 1993, p. 45) is predicated on the success of performativity, which underpins a basic presupposition of modernity education. Lyotard is against the legitimization of education through performativity, and on this point he is in agreement with Habermas, who as we saw questions the emphasis on assembly-line efficiency and productivity as an end in itself into which the individual in the capitalist and late-industrial society is increasingly abducted, not educated. Fritzman (1995, p. 60) explains the disquisition—which Lyotard Lyotard (1984, pp. 4–5) has with Luhmann’s ideology more than with Habermas:

> ‘According to Lyotard, those who advocate the legitimation of education through performativity call for abandoning the principle ‘that the acquisition of knowledge is indissoluble from the training (*Bildung*) of minds, or even of individuals’. Indeed, Lyotard believes that the concept of education as *Bildung* has been largely abandoned. The friends of performativity urge that pedagogy should impart only the knowledge and skills necessary to preserve and enhance the operational efficiency of society. For these persons, operational efficiency is determined by the results of cost-benefit or input-output analyses. Society is conceived as an over-arching, totalizing system that is constituted through the interactions of its subsystems. These subsystems include the economy, the family, politics, and religion. The content of what is taught is determined by the technological requirements of the system, and educators are evaluated by how efficiently this content is conveyed. When education is legitimated through performativity, Lyotard, notes, knowledge is not thought to have any intrinsic worth. Instead, knowledge is valued only as a commodity that can be sold; it no longer possesses ‘use value’ but only ‘exchange value’.

So this is one side of Lyotard’s critique that argues that the goal of pedagogy is not collect information, or to arrive at universal consensus through discourse (as for Habermas), but it rather marks ‘the search for new ideas and concepts that disrupt and destabilizes previously existing consensuses’ (ibid, p. 61), which is the preserve of the arts studied through a language one is either born in or is trained in. ‘Postmodern education is not simply a tool of the authorities; it refines our sensitivity to differences and reinforces our ability to tolerate the incommensurables. Its principle is not the expert’s homology, but the inventor’s paralogy’ (Lyotard, 1984, p. xxv). In other words, *the differend* (Blake 1998).

But even more importantly, Lyotard’ s real concern, I believe, is in attacking the emancipatory pedagogy for its ascription to the notion of freestanding autonomous subject self-fashioned through free will and good intentions (McLaren, 1995, p. 94). That is the notion of the *individual.* Instrumental actors, as distinct from the *person,* that pre-modern and traditional societies had recognized, that is believed to command its own signifying chain of agency, and may or may not opt to participate in the political because economy is seen as an autonomous sphere separated from the public sphere, while so alienated, he is will readily abrogate to himself rights, and privileges, and other free-range 'commodities' of a civil society. Lyotard, of course, challenges the autonomy of the subject, for the subject is already fore-closed in the social power relations and instrumentalist agenda of the technoculture. Or as post-colonial writers, such as Chow (1993, p. 36) and Spivak (1993, pp. 217–242) would have it, or the subjects further down as it were the subaltern ladder, 'the speaking subject belongs to an already well-defined structure of history and domination'. To the incommensurability of the capitalist/technoculture individual vis-à-vis the self-liberating postmodern, add the 'third-' developing world's muted and often invisible subaltern subject: where are we to locate this *not-yet-subject, the deferred differend,* in the postmodern (say, Butler's sense) in Lyotard's paralogy. This is precisely why I thought of reading Lyotard against the grain of Gandhi, backwards as it were, to be instructive here. Paralogy, as may be seen, is much more ambitiously expansion in the areas of arts and aesthetics, and indeed also the classics, than Gandhi's *Nai Talim* pedagogy had envisioned.

Nevertheless, I wish to argue that Lyotard's own life and career goes a long way towards making this narrative possible, in as much as it exemplifies the goal he sets for the truly educated. And yet, he appears to be restrained, he holds back from a full-commitment to the political—in the sense of the intellectual's responsibility to exercise her agency (not the falsely autonomously grounded free-by-choice actions in the economy of the market sites—as a fully fledged activist, ready to lay down her life for the cause one is passionately committed to, to as it were throw a total '*satyagraha*' at the enemy, nor the institution in need of destabilization. Gandhi once remarked as the of-(and rightly), horrors of the Auschwitz (which is badly misquoted often) that if sufficient number of European and Jewish intellectuals had cared to arm themselves with the weapon of satyagraha and march into the Nazi camps, disarm the SSS-troopers through sheer humility, an appeal to truth, Hitler might well have surrendered well before the holocaust occurred. Something that Heidegger could have done had he swapped the right hemisphere of his otherwise genius brain (and looks) with Hannah Arendt's and Karl Jaspers'. Lyotard was of course keen that postmodernity learns a bitter lesson from Heidegger's complicity in the self-destruction of modernity in the naming the Auschwitz, but the question remains, from as it were the third-eye/world position: was Lyotard prepared to go 'all hog' himself and was then his paralogy and the supplemental pedagogy sufficiently saturated or sutured to achieve that end?

As recounted in the Introduction, Lyotard up till 1969 was involved in the Algerian question and also supported the struggle against colonialism—hence his sympathies for the plight of the natives and subaltern in this context is unquestionable. Laudable also is the fact that he was engaged in his own practice as a *lycée* professor in Algeria. By 'engaged' one means an 'engaged teacher' in the discourse of the public sphere, and in the asymmetry he underscores in the teacher/pupil relationship which the institution of authority marks more symmetrically. And he undertook more direct and decisive political actions at Nanterre University. Education is political.

However, in the 1970s and since, Lyotard took the Socratic-gadfly turn, a Voltairean Nietzsche writing and pushing for *puissance* on the edges of modernity's near collapse through contradictions within its own *discours*¸ the engagement henceforth is of the text, and the destabilization is focused on discourse, calling for the abandoning of grand narratives and self-certainty of the sciences, and so on. We might call it breaking the rules of the game, while however still located in, albeit uneasily but not entirely outside of, the text and in the professor's privileged chair. Hence what seemed lacking is a complete commitment to any sort of *Programm* and/or enlisting of religious interests in the political sphere—even for its sweet *jouissance.*

Concluding Remarks

In conclusion it would seem that Gandhi's concerns with the extent of the destruction that colonialism and its agency capitalism was causing would far outweigh in the history of the 'West' that was being made, would rather rapidly bring down the towers of modernity: and so this fight had to be taken, an intellectual could not be short-changed. The goal of education produced such destabilizing persons who at the same time are loyal to a community to which they devote the life: the two seemingly antinomian kinds of discourse are not incommensurable. A pre-modernist combines and foreshadows elements of the postmodern and post-colonial as well. The dual '*post-*' here registers Gandhi's recognition that while the whole rational heritage of scientism/modernity/progress as championed and practiced by the 'West' has achieved a great deal during the last four centuries, this legacy has now reached its 'logical' limits of utility and relevance. 'Progress' itself is being questioned and is becoming questionable as a desired goal: it has crossed the threshold of the 'excess'. An ancient Sanskrit axiom enjoins, *athi sarvatra varjayet*: excess should be shunned everywhere (Babu, 2001). In more prosaic terms, globalization and liberalization through the increasing invasive presence of multinational corporations as ravaged India's textile industry (not to mention Gandhi's home-crafted khadi), the agricultural and ecological self-sufficiency. As a recent Trade Union leader, Babu Mathew, observes, 'Modernity might have freed people from shackles… but it is now going to reinforce capitalism. You can release bonded labourers but they are going to be reintegrated into the worst form of bondage. Modernity is traveling so fast it is going to tear societies apart. We have an opportunity to develop a new critique of modernity' (Meena, 2001). And he defers to the Gandhian model and to people's informed initiatives and action.

Habermas, for his part, is equally critical of the capitalist society enamoured of the *technē* of science and its performativity culture—the efficiency and economy of skills that produces more and more for the sake of producing, and consuming—but he believes the universal project of modernity is 'incomplete', within the more radical planks of the Enlightenment itself. Lyotard too rejects performativity and believes modernity has reached its zenith point of excesses, which is beginning to undermine the Enlightenment rational choice paradigm from within; he holds education or its failure in the schools of modernity, as much responsible for continuing this malaise. And this is his argument with Habermas, that unless there is a radical shift in pedagogy towards paralogy—defined as the ongoing creation of meaning derived from exercising basic capabilities in the arts, aesthetics, critical thinking and language—there is little hope of redeeming even the best of the traditional ‘Western’ legacy, let alone of the rest of the globe. Lyotard however is not as such interested in a return to or retrieval of the pre-, the pre-modern, or the pre-Europeanization of the world, for that would only perpetuate the old *logocentricism.* But apart from his activism in Algiers (which was against French colonialism), Lyotard seems to show very little awareness of plight, predicament and poverty of the ‘developing world’: in short, of the post-colonial condition. Thus, if the driving force of science and technology is economics or the market, poverty will not be addressed. Yet, it is his discourse that has tremendous possibilities and indeed has provided a refreshing basis for a critique of modernity to many a post-structuralist, post-colonial, and feminist writers from India and Asia at large (supplementing the Frankfurt School, Foucault, Derrida, Kristeva et al.).

Now, I have found no reference to Gandhi in his entire work, although I suspect the recurrent reference to ávatar’ may have a distant signified echo in the international presence of Gandhi—for surely in Algiers he would have known it was Gandhi who threw the first stone at ‘Western’ colonialism? In any case, it appears to me at the end of the day that Lyotard is poised somewhere in the middle between Gandhi and Habermas, for the reasons I have argued in the third part of the chapter. He remains perhaps an exemplary *amśa avatāra* [a miniture avatar] but certainly a *mahabodhisatva*, or *megalopsychia,* Aristotle’s sense of a proven ‘great soul’, and that is exactly the kind of postmodern intellectual paralogy and the particular pedagogy he builds on this disturbing discourse is intended to yield. And herein also lies the seed for a synthesis of Gandhian pedagogy of productive education and Lyotard’s intellectual paralogy, that interestingly enough sprouts, more or less, in the aesthetically nuanced educational praxis of Gandhi’s friend, Rabindranath Tagore, that he experimented with in Shantiniketan (‘ashram-school’) outside Kolkata, in West Bengal. Space does not permit us to explore this happy conv(em)ergence here. Thankfully, a recent study ably succeeds in capturing the gist of Tagore’s unique achievement in this area (Ghosh, 2017), for which he expressed gratitude in part to Gandhi’s inspiring and exemplary life (in fact, it was Tagore who bestowed the title of ‘Mahatma’ onto one of the unmistakable avataric presences of the twentieth century).

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Chapter 4
Art, Science and Language: Teaching Tools of Aborigines in India

Rajunayak Vislavath

Abstract In this chapter, I explore the ways in which the Aboriginal communities in India utilize indigenous artistic, scientific, linguistic, and cultural resources to teach members of their own communities a scientific understanding of nature. I also look into their usage of culturally specific short stories to impart knowledge and skills of science and technology required for application in their daily life.

> The reason why language plays such a significant role in the new capitalism is because of it being 'knowledge-driven', that is, constantly generating knowledge about the world and how people are to act in the world (e.g. in the workplace). For this, it has to rely on language or discourse, discourse that is 'endowed with the performative power to *bring into being* the very realities it *claims* to describe.
>
> (Fairclough, 2003, p. 203–4; emphasis added).

In the contemporary world which is controlled by capitalism as well as in the world before the advent of capitalism, language always played a very important role as Humboldt propounds, man "spins language out of himself, he spins himself into it" (Humboldt, 1998, p. 60). For the marginalized populations, language becomes even more important because it is the site where interaction and conflict of different ideologies takes place; therefore, literary texts, being complex clusters of language, become extremely fecund sites for such ideological interactions become the complex articulation between a single individual, social contexts and the play of language. Ngugi wa Thiong'o (1981) establishes a relationship between language, literature, culture and various other discourses when he says:

> Language carries culture, and culture carries particularly through orature and literature the entire body of values by which we came to perceive ourselves and our place in the world. How people perceive themselves affects how they look at their culture, at their politics, and at their social production of wealth, at their entire relationship to nature, to other beings (Thiong'o, p. 16).

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Language is perhaps the most important marker of ethnicity and identity. Apart from being an indicator of artistic and cultural distinctiveness, it forms a significant aspect of the culture and identity of an individual as well as a community. In India, there are a considerable number of non-dominant languages used for articulation by Aboriginal communities or indigenous ethnic communities. Presently, the indigenous languages and cultural art forms originating from these languages are overlooked in both public and academic discourse due to a combination of a number of complex sociopolitical, cultural and economic factors.

The continuous privileging of only a few officially recognized languages within national and global circuits of communication has led to the gradual domination of these indigenous languages by the mainstream languages resulting in not only an endangering of the former but also initiating an erosion of indigenous identity and ethnicity. The state's efforts at preserving these languages and the cultural identities of the communities by museumizing them have done little to enable serious academic research regarding the problem.

In this chapter, I explore the ways in which the Aboriginal communities in India utilize indigenous artistic, scientific, linguistic and cultural resources to teach members of their own communities a scientific understanding of nature. I also look into their usage of culturally specific short stories to impart knowledge and skills of science and technology required for application in their daily life.

In India, "tribal" or indigenous people, or what I will call indigenous or non-dominant group,[1] constitute 8.2% of the population, i.e. 84 million people, according to the 2011 census. Each indigenous group has its particular language. These indigenous languages are endangered and on the brink of extinction. As of now, there are about 187 languages in India. The majority of them are indigenous and under threat of sociocultural disappearance. At present, there are 33 nomadic groups called "Scheduled Tribes" in Telangana and Andhra Pradesh speaking their own languages. These are the Lambadas, Koyas, Yanadi, Erukalas, Gonds, Konda Dora and others. However, their languages are not officially recognized by the two state governments and the central government of India.

Since India as a nation was structurally formed on the basis of different regional–linguistic sub-nationalities, the languages of the indigenous communities have never been considered dominantly popular compared with the mainstream regional languages such as Telugu, Urdu, Hindi, Marathi, Bengali and others. Therefore, these non-dominant languages are mostly unrecognized by the state. Priority is accorded to the recognized official languages for governmental, administrative and legal purposes. Since they are not used by the state, these languages run the risk of being pushed into official oblivion, along with the distinct cultural identities of the indigenous communities. They have reached a stage where they can be called aphasic that is those who suffer from language loss.

[1]The word "tribal" is synonymous with the negative connotations implied by ideas of primitiveness, uncivilized state and barbaric images. The terms "Adivasi" can be used in the Indian context and would essentially bear the same notions which modern neutral forms such as 'indigenous communities' or 'ethnic communities' possess. They can be used interchangeably. However, the Government of India uses the term "tribe" in its official discourse for various administrative purposes.

Among all the indigenous communities, I will mainly focus on the Lambada community from Telangana in India. Lambadas are spread all over India and the language which they speak is called "*Gor boli*",[2] but the interesting thing is that they adopt the regional languages as well, depending on where they live. They use Hindi, Telugu and English words. Lambadas are thus combining their language with the various mainstream languages. Amidst such a dynamic process, the borrowed words or loaned words are well understood by the listener within a given context without any difficulty. Thus, language is an ever-flowing stream of speech in which nothing remains fixed and identical to itself, and secondly language is the stationary rainbow arched over that stream (Volosinov, 1973, p. 6). Language further constitutes a site of power. Devy and others evoke an argument similar to that of Ngugi Wa Thiong'o where they write:

> Language is power. It has the power to upset, uproot and shackle…if you name the world, you own it. If you are dominated, you see the world through the eyes of the conqueror, effectively burying your memory under the conqueror's memory" (Devy et al., 2013, p. 125–26).

The latter is perhaps what is happening to the indigenous communities in India. They are gradually being dominated by the mainstream languages such as English, not only do these languages disappear they also lose indigenous cultural identity and ethnicity. Moreover, in schools, most of the indigenous children are facing problems with learning since they are adopting English as the medium of instruction. Terry Eagleton claims that, "No piece of language is closer to reality than any other" (Eagleton, 2013, p. 126). The English that is taught in schools across India is not familiar to the indigenous communities, and they face a constant language barrier. They are more familiar and conversant with their native languages. The schools and teachers mistakenly assume that the indigenous learners should have the ability to learn and perform along with students who have access to the English language. As a result, they lag behind in the learning of new subjects. The classroom instruction does not match the reality of the language spoken in the home. Eagleton further argues that, "meaning belongs to language, and language distils the sense we collectively make of our world" (Eagleton, p. 145). As a native child, he/she interprets a world in which he/she grows up by trying to find the different meanings. Introducing a new language to a student belonging to the indigenous community does not allow his/her worldview to be explored in the school. Similarly, Zehlia Babaci-Wilhite writes that:

> The teaching of science in Africa suffers from a pedagogy grounded in its colonial history… Colonial education in Africa is not transmitting the values and the knowledge of African society from one generation to the next; it has involved a deliberate attempt to change those values and to replace traditional knowledge by the knowledge from a different society (Babaci-Wilhite, 2016, p. 3).

If they are taught in indigenous languages, there is perhaps a chance of avoiding dropouts in Indian schools. Further, Babaci-Wilhite also says that, "to motivate the active mind, one has to take into consideration the variations in differences in knowledge and different ways of teaching to achieve quality education" (Babaci-Wilhite,

[2] A tribal language, which does not have script.

2016, p. 3). Most young indigenous students think that the syllabus and curriculum in educational institutes lack relevance. Therefore, it violates the basic human rights of the education of the marginal sections in India. Thus, to avoid this human violation one needs to bring local languages into the modern pedagogy to make STEM subjects interesting. Otherwise, as Pasi Sahlberg claims, "Students seem to find the teaching offered in schools and universities increasingly boring and irrelevant to their needs in a rapidly changing world" (Sahlberg, 2015, p. 3). The ultimate goal of education is to provide knowledge and to develop overall skills to the students so that they are able to explore their worldview. An inclusive education must encourage communication in indigenous languages by incorporating indigenous methods of teaching and bringing diverse egalitarian knowledge into the educational spaces to provide adequate learning opportunities to all the children in India. The indigenous methods are not oriented towards any institutionally prescribed syllabus or classroom teaching. Instead, the children learn from their everyday life experiences that teach and train them for the future. That enables them to face the challenges of the world in which they live.

Marginalization of the Indigenous Literature

The central argument of this chapter rests on the fact that one of the ways in which one could understand indigenous issues is by analysing the Bhat narratives. The Bhat is a sub-community of Lambadas that sings songs for the Lambadas in *Gore boli* (the Lambada language). The Bhats in Telangana have a rich oral culture. They narrate the social and cultural histories of Lambadas in the form of songs. These songs generically belong to oral histories, of the subaltern Lambada groups and their subgroups. They question the knowledge disseminated about them through written historical sources. Unfortunately, the Bhat narratives have neither been paid much attention to by writers and scholars nor do educational institutions include them in their curricula, an important factor in developing interest among the students regarding the histories of these communities. The main reason for this epistemic relegation is the dominant belief in the importance of writing itself. It grants academic legitimacy to the documented histories described mostly in print. Consequently, oral narratives specifically and the significant body of the oral literature in general remain relatively unexplored by scholars. Moreover, the popular representation of indigenous communities in mass media inhibits scholars' ability to think beyond stereotypical notions associated with these communities and their culture. In the last two or three decades, academic interest in the subaltern histories and the marginalized literature has grown due to the increasing demographic participation of scholars from unprivileged backgrounds and the resultant ideological and pedagogic strengthening of these subjects. For instance, Dalit writing has been able to enter the university curricula and classrooms in a major way because of the gradually increasing presence of scholars from Dalit and Scheduled Caste sections. In general, there are fewer academicians and scholars from the category of Scheduled Tribes. Vibha S. Chauhan argues that:

> …unlike the "Scheduled Castes", the protests of the "Scheduled Tribes" have still not got consolidated into a social, political programme with the potential of impacting the policy-making systems of the state. There has been no clarion call like the one made by B.R. Ambedkar for the Scheduled Caste to "educate, organize and agitate". Unlike the Scheduled Castes, who have successfully managed to bring themselves into a bargaining position, the Adivasis are still pinned down to the periphery (Chauhan, 2013, p. 57).

On the basis of the data collected regarding faculty recruitment in four major central universities in India, it is evident that the posts reserved for Scheduled Tribes are less when compared to the Scheduled Castes (Komaraiah and Singh, 2014, pp. 59–60). The general minuscule representation of scholars and academicians from the Scheduled Tribes category leads to fewer teachers from such backgrounds being incorporated into public bodies set up to oversee overall academic practices within universities (like the syllabus designing committees). The language issue compounds this problem. While the most Dalit literature is written in the major Indian languages and thus can be understood by most academicians, narratives of indigenous communities are not available in major Indian languages. Further, academicians aside from than those belonging to the indigenous communities seldom speak these languages (Rajunayak, 2013, p. 39). Thus, only those scholars who know these languages and dialects are equipped to study these narratives. It is that there is a certain academic apathy towards the histories of indigenous communities within the Indian academy. An institutionalized effort at introducing these narratives and the knowledge systems of these communities is completely lacking. These indigenous songs and other cultural productions are the only sources by which the social values, moralities and ethics are transmitted from one generation to the other. They also record the historical and contemporary political struggle of these communities, making them relevant to the academic discourse.

In order to understand the issue of the marginalization of the non-dominant literature, it is also necessary to look at the popular and dominant notion of the literature itself. In the literature departments across universities in India, an emphasis is given to the literature from "West" with the principal focus on the new critical and formalist theories of the literature, which give primacy to the written word. According to these theories, only particular genres such as the novel, poetry, drama or the essay are considered literary for teaching and research purposes. Quite understandably, indigenous oral narratives are excluded from these literary discourses. However, Terry Eagleton argues that there is no such thing as a literary work or tradition that is valuable in itself says:

> Literature, in the sense of a set of works of assured and unalterable value, distinguished by certain shared inherent properties, does not exist. On the other hand, the value judgements that the literary authorities make have their roots in "deeper structures of belief" and are "historically variable" and have a close relation to social ideologies. They refer in the end…to the assumptions by which certain social groups exercise and maintain power over others (Eagleton, 1996, p. 9).

Subscribing to Eagleton's analysis, one can argue that what matters is the text whether it is written or oral. Thus, we can extend the argument to state that the culture and identity of the Lambadas can be textually constructed through their oral narratives which qualify for intellectual and scholarly analysis. Then, it becomes possible for us to construct a different version of history as opposed to one written from the perspective of the politically hegemonic sections of the society. This points to an urgent need for studying the Bhat narratives, which are literary texts in as an alternative to what is indicated by the usually accepted term "literary".

The Bhat narratives are prominently both verbal and non-verbal. They constitute a potential area for constructing indigenous social histories, especially the historical and contemporary life of Lambadas. Most of these narratives do not conform to conventional popular genres of the literature. Comprised of mainly proverbs, "joke games", riddles, tales and oral epical dramas, they are used by the Lambada Bhats and transmitted orally to a largely non-literate audience composed of children as well as adults.

Oral narratives of the Lambada Bhats teach and educate the community in various ways. Until recently, no other form of knowledge has been available to the Lambadas. The song below is an example:

Lakidi kate Lakidi Kate deko bhai Lakidi kate
Lakidi katen kuppa mele kupama pandra lakidi
Pandra lakidi maiti sath kade azi katri lakidi kedo ro bhai (Ramjohl 2016)

Translation

We cut the trees see my brother we cut the trees
After we cut the trees we put together and count total trees
Total we cut were fifteen
Among the fifteen we take out seven how many trees remain there?

The above song teaches calculation to the community. It is not that they are cutting the trees. They cut only the unused trees for lighting fire.

Another song which Lambadas use as a teaching tool in the community is:

Jhad katomath Lakidi manth koto,
lakidi katatho jhad katatho pani mareni
Pani marenitho panta pacheni
Panta panchenitho dhanmaleni
Dhanmaleni tho manikya bancheni (Balunayak Porika 2016)

Translation

Do not cut the trees and do not cut the wood from the trees
If you cut the trees and wood you do not get the rain
If you do not get the rain
You do not cultivate the land
When you do not cultivate the land
You do not have the food

Serious academic research undertaken on such topics is rare, but without further investigation it is quite difficult to understand the Lambadas or indigenous communities.

Contrary to the common perception that the indigenous or folk literature deals with pre-modern societies or cultures, the Bhat narratives engage with the realities of the modern world. Through their narratives, the Bhats simultaneously establish their own experiences and those of the Lambadas as they interact with the modern civilized world. The Bhat narratives or performances draw our attention to a popular construction of ideas concerning modernity and its agencies. The Bhat narrators deal with everyday transactions rooted in modern institutions such as banks and other institutions of the state, drawing our attention to the discursive dimensions of what constitutes modernity.

Xaxa (2008) points out that in the anthropological literature, tribes in general have been defined in terms of language, culture, territory and government. I would like to emphasize this pertinent issue related to indigenous languages and their multiple usages. At present, indigenous languages are overlooked within academic discourse and the linguistic identities of the indigenous communities are ignored by the mainstream society. In this connection, Saumya discusses how the processes of "othering" work in the course of identity formation:

> Identity forma-tion usually is a cultural construct, a process of inclusion and exclusion of values and symbols defining "we" and "they" or "us" and "others". Relationships between "we" and "they" are not inevitably always conflicting or competitive but when it takes a political form, differentia-tions between "we" and "they" get pro-nounced, prejudices become prominent and boundaries for interactions… (Saumya, 2008, p. 38).

Increased deforestation and human settlement by the indigenous communities have increased contact with the modern society. It actually puts the languages of these communities at constant risks of being obliterated. Indigenous languages might simply vanish by being forced to merge with the linguistic practices of the majority of the society. This would be a loss, not just for the concerned communities but for the overall cultural knowledge pool of India. I will later demonstrate how these settlements affect the oral narratives and songs and the languages of the Lambada in general. Edward Sapir (1921) puts forward what is known as the Sapir-Whorf hypothesis:

> Human beings … are very much at the mercy of the particular language which has become the medium of expression for their society … the 'real world' is to a large extent unconsciously built up on the language habits of the group … we see and hear and otherwise experience very largely as we do because of certain choices of interpretation (Sapir, 1921, p. 207).

Whorf goes on to add, "we dissect nature along lines laid down by our native languages" (Sapir, p. 212). What we mean by the indigenous ethos is concentrated primarily in their languages. It is the language that forms a significant part of their subconscious and gives them a distinct identity.

It is common knowledge that language is culturally embedded. Cultural change is often accompanied by a change in ideas and idiomatic expression. In the age of the computer and technology, the Lambada community faces an identity crisis, since their life and culture are being completely unexplored and excluded from the public discourse. There is an increasing anxiety among the lambada in regard to the ways that their language can be established as a part of a larger human inheritance. Therefore, the Lambada language and other such indigenous languages need to adopt written forms to push them into the light of modern-day scholarship and make them eligible for multidimensional research.

Language as the Specific Object of the Study Keeps Eluding Us

"Language" is a unique gift to human beings that enables them to distinguish themselves by their unparalleled ability to communicate and share feelings using common "codes" to understand ideas, feelings and experiences, as they are articulated by individuals and collective groups. Language has unique features the primary one being the process of change. Considering a language as a living entity, it is bound to evolve with time adopting new forms to facilitate the act of communication in society.

However, language and its usage and expression do not change drastically. Linguistic exchanges with neighbouring villages, cities, states and countries at large cause a language to slowly adapt using some words from other languages. For example, English has borrowed words like chutney, khichidi and others from the Indian languages. Lambadas also borrow words when they move to other regions or they adopt some words by listening to modern songs. For example, the following song has many words from English and other languages.

Transliteration

Apan ghar *bus* keri hubiye—beta taro sasaro balayen ayo
Jaoni ye sasureri lare—ayeo apana ghar *takter* keri hubiye
Beta taro jete balayen—jaoni ye hame jete laree
Aye apan ghar *car* keri hubiy—beta taro devare balayen ayo
Jaoni ye devareri lare—ayeo apane ghare *lorry* keri hubiye
Beta tare nande balayen balayene ayee—jaoni ye hameri nanade ri lare
Ayee apan ghare *cycle* keri hubi—beta taro darvani balayen ayee
Jaoni ye darvani re lare—ayo apane ghare *scooter* keri hubi
Beta tari jatani balayen aye—jaoni ye jatani ri lare
Ayo apan ghare *Luna* hubiveri—beta taro vayavalo balayen ayo
Patiyaso matho gontho bovoji—patiyama churmo churun jao
Luna chadan lego daniya.

Translation

Whose bus is standing in front of the house?—Daughter your father-in-law has come here to take you

I don’t want to go with my father-in-law—whose Tractor is standing in front of the house?
Daughter your brother-in-law has come to take you—I don’t want to go with my brother-in-law
Whose car is standing in front of the house?—Daughter your Driver has come to take you
I don’t want to go with my Driver—who has come by the lorry?
Daughter your sister-in-law has come to take you—I don’t want to go with my sister-in-law
Whose cycle is this standing in front of our house?—Daughter your elder sister has come to take you.
I don’t want to go with my elder sister—whose scooter is standing in front of our house?
Daughter your younger sister has come to take you—I don’t want to go with my younger sister
Whose Luna is standing in front of our house?—Daughter your husband has come to take you
Round head (like a pot) comb it, my friends—mix the sweets in the pot my friends
I will go on the Luna with my husband.

The Lambadas are nomads who travel from one place to the other coming encountering various kinds of people and languages, and they have faced this sort of inter-indigenous interaction for decades. They borrow many words from other languages because they have to communicate with various people in life. Even though they live in separate hamlets, far away from the mainstream, they still interact with other people and use their language. In the above song, all the italicized words are English words.

The Lambadas use these unfamiliar English words in the song, even though the pronunciation is difficult, and they use the words without any inhibitions. Due to the impact of globalization and mainstream dominant cultural practices, the Lambadas are finding it difficult to speak their own language. However, since they need to communicate with other rich communities to survive, they have no option but to speak the dominant language, Telugu, which to them is a foreign language. As a result, there is an increasing tendency to not use the language in which they communicate most easily. As a result, there is a process of assimilation in terms of linguistic and cultural behaviour. This is demonstrated clearly in the song above. From the adoption of a modern lifestyle and the incorporation of existing hierarchical structure present in dominant languages and cultures, it is quite clear that they have borrowed and assimilated other dominant languages for material purposes. When they use these words, the cadence of the song changes and a modern style of singing takes place. In this song, one finds an indication of class identity separate from familial relationships. Generally, people in villages do not allow women to ride a cycle, scooter or any other vehicle; however, in this song the indigenous communities use all the modern tools aspiring to be on the same sociocultural plane with the other advanced communities. The indigenous communities were not aware of gender hierarchy as practised among other communities rooted in patriarchy. However, they now tend to practice such discrimination in their social life. This change can be reflected in their use of language as well. Furthermore, language is encompassed by the unity of the immediate social situation; i.e. the social exchanges between individuals and communities often leave indelible impressions on the syntax, lexicography and morphology affecting the semantic reception.

In case of semantic reception, the context makes it convenient to infer the meaning of the word. It is not necessary for both the speaker and the learner to have a common understanding of the particular word that has been referred to during the course of a linguistic exchange. The context fills the gaps in meaning even if the listener has been recently introduced to the particular word. Thus, new words are slowly assimilated into a language and register themselves as components of that language. This movement and absorption of words into a particular language are not a new phenomenon; it is as old as the institution of language itself. It has become more prominent with the exchange of ideas, traditions and customs among people. Moreover, the improved transport system and technological innovations have also brought major changes in language. What this exposes is that, from the perspective of language generation, the vital feature of grammaticality of everyday speech is contextually perhaps unimportant for the common people to communicate easily.

The simplification of sound basically allows the speakers to modify and convert difficult sounds to easily communicated ones. The most recent theory pertaining to this was by the American Linguist William Labov. What Labov (2010) found that at the beginning a small part of a population pronounces certain words that have, for example, the same vowel, differently than the rest of the population. This occurs naturally since humans do not reproduce exactly the same sounds. However, at some point in time, for some reason, this difference in pronunciation starts to become a signal for social and cultural identity. Others in the population who wish to be identified with the group either consciously or (more likely) unconsciously adopt this difference, sometimes exaggerating it, and at times applying it to change the pronunciation of other words.

There are instances where some words from English have seeped into the Lambada narratives. For example, people are coining terms like “cyber pad” and “dotcom” borrowing them from ideas associated with computers and science and technology. The example below will show the introduction of these new words in the daily practices of the Lambadas.

Transliteration

Dher vego tien chachar kantha karlaye *apirition*
Bara chachar chavache maan pati karahoni *apirition*
Jibema lejaho tone kantha karaley *apirition*
Bayasun oee *jibema* pati karauni *apirition*
Roji roji bati boti ghalnu tone kanta karle *apirition*
Sobotema lejaho tone kantha karle *apirition*
Sobotem auni pati karauni apirition.

Translation

Enough we have three kids kantha go for operation
Twelve kids, I need a husband I won't go for operation
I will take you in jeep kantha go for operation
I don't want to sit down and I won't go for operation
Every day I will offer mutton kantha go for operation
I will come with you kantha go for operation
I won't come with you husband, I won't go for operation.

"Langa, station, military, hava, phone, beer, whiskey, mander, terikat sado, rile" are few of the many new words that the Lambadas have borrowed from various sources.

It is observed that children of immigrants almost always learn the language of their friends at school regardless of the parents' dialect or original language. Learning a new language opens up new possibilities for exploring and describing one's perceptions, thoughts and beliefs, hopes and aspirations. The class of Lambada is mobile in nature and adapts to the modern political, economic, social and cultural fabric of the urban city life.

They use the newly learnt words hesitatingly at initial, but after a few days they are subsumed within their regular speech. A cursory glance at the array of professions in India makes one realize how important a factor this must have been in the pre-modern Indian society and also how the occupations and language have lost their relevance in today's society.

The majority of the Lambadas are economically not affluent; sub-communities such as *Bhats, Dapdiyas and Navies* are always dependent on the upper clans of the Lambadas. The fundamental issue with most of these communities is an acute sense of loss pervading their lives—loss of occupation, social status, dignity and honour, and the legitimate rights. These communities seem to carry diverse kinds of historical and cultural burdens that are expressed through their languages.

Technology in Language and Culture Development

Due to the development of railways and other modern transport systems, the Lambadas lost their small-scale businesses that affected their economy adversely; when patrons become poor, it affects the patronized too. Therefore, other dependent communities like the Bhats, Dapdiyas and Navies were also indirectly affected. They stopped narrating the songs bearing their historical legends. They were compelled to look for other economic alternatives and began migrating to urban centres to work as construction labourers and in other blue-collared jobs. These indigenous communities actually went through different stages that caused a rigorous and fundamental rethinking of their narratives. Their oral and folkloric elements become important for multi-layered research along the lines of humanities and social sciences. Given the fact that the Indian cultural fabric is quite complex and bears the impression of numerous communities throughout its history, an intimate and rigorous exploration of the oral forms of the marginal indigenous culture, the histories of the nation and also the popular historiographic traditions cannot be ignored.

The oral resources available in Indian languages could throw a new light on a genealogical understanding of the present history of India. The present history is mainly dependent on documents in the written form under the influence of continuous Sanskritization. The indigenous oral texts would offer insights into the alternative history of the communities of India and would change the way in which the colonial and post-colonial Hinduized sections look at these communities. Such an inquiry would be topical as well as deeply historical and might facilitate a re-imagining of Indian history.

This kind of work makes use of the critical mechanisms of chronicling-cum-historicizing the available oral narratives of the Lambadas in order to extract the sociocultural significances of these specific cultural productions as well as the general oral narrative traditions. The co-ordinated scientific academic efforts could help in the unravelling of the evolving histories of the Lambadas. They would reveal the ways in which the identities of these communities were carefully constructed during the colonial governance, sustained with time, and later after the independence absorbed by the new efforts at nation-building on the basis of parliamentary democracy and linguistic–cultural order. These will illuminate the strategy of conserving these identities in order to change practices that have maintained a monolithic and homogeneous cultural view of these communities that is popularly reflected currently in the mass media.

After the formation of the state of Andhra Pradesh, the Telugu language has been given priority over a multilingual education system that existed during the period of Nizam's rule in Hyderabad. As the institutions started using the Telugu language as the medium of teaching, children from indigenous communities started to drop out. The nationalist project of imposing the Telugu language on these communities demonstrates a deployment of an instrument of cultural hegemony. With such historical changes, some non-dominant languages have disappeared while the rest face at the prospect of extinction. There are various questions for the state to answer in this regard, especially regarding the importance of protecting these non-dominant languages. It has become imperative for a speaker of these languages to be conversant in other dominant languages like Telugu, English and Hindi to receive an education and be meaningfully employed. This favours certain languages and marginalizes the indigenous languages, something that experts and scholars need to think about. The absence of texts for the indigenous languages becomes a strong reason for such marginalization. However, India's official language Hindi uses Devanagari script. The question of the script is secondary to the intention of officially acknowledging a language or a dialect on the basis of its popularity among the people (Bhukya, 2012, p. 4). This would inevitably lead to the development of suitable script and grammar for the language. The present political society seems to ignore and neglect developing multilingual systems for important public purposes such as education. There were attempts to introduce and nurture indigenous languages as the languages of instruction in certain parts of the world (Babaci-Wilhite, 2013) and by the Nizam of Hyderabad as well.

The last Nizam, Osman Ali Khan, recognized the importance of the indigenous languages. He recruited people from these communities and trained them for teaching. He appointed some of these teachers to translate all the important texts into indigenous languages such as Lambadi, Gond language and Koya by using the Telugu script. This multilingual teaching continued till 1956 and the formation of Andhra Pradesh which focused on Telugu, while other languages were neglected. In fact, the Dhebar Commission (1960–61) recommended the recognition of "pedagogical ingredients in tribal culture and wanted to make use of tribal language and cultural resources, such as folklore, songs and history in teaching" (Report of the High Level Committee on Socio-Economic, Health and Educational Status of Tribal Communities of India, 2014, 155). However, the suggestions were ignored by the state adversely affecting these communities.

Today, we see the effect of these policies on the indigenous communities. The Lambada[3] *Thandas* are isolated from their villages which forces them to communicate in their own Lambada language b. Due to state developmental projects, such as open cast coal mines,[4] SEZs and water dam projects, the Lambadas are forced to migrate to other villages and cities in search of a livelihood where they start using other languages, thus acquiring new linguistic and cultural identities.

Human Rights and Equity in Education

The material being taught in schools, colleges and universities should improve and be sufficient to sensitize students from diverse backgrounds regarding questions of human rights and equity. Personal, scientific and political goals should merge in a quest for truth that would ideally free humanity from age-old dogmas. Seen from a progressive perspective, this discourse should help us understand the past and the present with more clarity. Reading and learning help to advance knowledge about the specific fields or the broader contexts in which these specific fields are situated. It unites the reader, speaker and listener in a symbiotic relationship that enables a subjective understanding of themselves, their relationship with each other and their position in the world. This is especially true for children who are at the preliminary stages of their education. Ideally, it would help them to be moulded as citizens of this world. Thus, an equal and egalitarian education system essentially enforces a better understanding of the world powered by peaceful social coexistence. In this context, the state should seriously think and discuss the domain of functionality in education.

Given the situation in India, it is instructive to look at a recent issue concerning California school textbooks. The California State Board of Education was revising the sixth- and seventh-grade history and social science textbooks accompanied by

[3]A place where Lambada tribes leave called as Thanda.

[4]Special Economic Zones.

sharp questions and pointed debates regarding the inclusion or exclusion of certain topics for teaching. Similarly, there is an imperative for a public debate in India as to the suitability of the language that is used for teaching the students who belong to diverse backgrounds. The key issue here is the tension between the dominant discourse of the colonizer and the counter-discourse of the colonized. This conflict, or rather the acknowledgement of this historical conflict, offers a model for how one can think of completely overhauling new syllabi for schools, colleges and universities across India.

Conclusion

The work for my research underlines the fact that the complex and chequered Indian cultural fabric cannot be traced without a vigorous exploration into the circulating manoeuvres of the marginal communities. In fact, the colonial period marked a significant turning point by trying to explore the idea of protecting and preserving the marginal cultures against the mainstream social hierarchy, especially in case of the indigenous communities. However, the hegemony of Hinduism misinterpreted the "marginal" groups' identity and their social dignity. However, to control these communities within the four-fold caste system, which they legitimized their unethical religious practices. Having maintained the intrinsic hierarchies, the processes of Hinduization and Sanskritization appeared to be a divine law that lacked rational sanction and scientific evidence. Yet, they managed to impose upon the non-dominant communities an inferior status in relation to the superiority of the caste-based religious dominant communities.

If the severe under-representation of the indigenous communities, especially the Lambada and Bhat Lambada communities in public life, is to be significantly transformed, it requires wide-ranging efforts from both individuals and collective formations, private and public agencies of the state. Otherwise, these communities will undergo a discursive death, whereby their entire past and contemporary history would be erased from public memory. This necessitates a reconfiguration within the institutions where objective academic studies on these communities can be undertaken as well as by scholars from within as well as outside the institutions. This would support the numerous strategies adopted by members of these communities to engage with the issues of historical past and a political present. Language here plays a key role, especially in gaining access to the reservoir of oral narratives, transcribing them in print and other modern formats for archiving and preservation. It would fulfil the three aims, firstly, preservation of the languages and cultural productions; secondly, enabling future research on specific issues related to these communities; and thirdly, exploring how STEM subjects can be used to study these marginalized communities and rewriting the complete history of India.

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Chapter 5
Fictions as Heuristic Tools—Toward an Understanding of Agency as the Foundation of Human and Linguistic Rights in the Curriculum

Beatrice Sasha Kobow

Abstract This chapter examines fictions as a heuristic tool in the learning of STEM–STEAM, which has been neglected in its epistemic relevance. Fictions are pragmatically relevant and action-guiding. Importantly, they facilitate insights into the structure of agency. Considering Walton's 'Mimesis as Make-believe' and its recent application in a discourse on model-making, I take the intentional–representational aspect of fictions to be one key of this epistemic point. Vaihinger's 'Philosophy of the As-if' highlights the pragmatic agential purpose of fictions as a form of judgment. Taking these insights from Walton and Vaihinger, I argue that fictions promote an understanding of agency. Understanding agency is a fundamental right, which is foundational for linguistic rights in education and needs to be implemented in educational contexts. A reconsideration of the foundations of our curriculum with a view toward human flourishing will focus on different heuristic tools, such as fictions, which foster an understanding of agency.

Introduction: Investigating the Foundation of Our Curriculum

The aspects of 'permanent contingency' (as a continuity of intentions and expectation of the success of actions) and 'linguistic constitution' (as the linguistic transfer of status functions to establish rights and obligations) together comprise the knowledge of the horizon of (human) agency, which is the framework within which agency is

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possible. Coming to know oneself as an agent and learning to be one is the central tenet of an educational agenda that empowers the individual.[1] Incidentally, the antique notion of eudaimonia is also predicated upon the knowledge of what is up to me and what is out of my hands—the very distinctions we are aware of in understanding agency.[2] Often we must suspend judgment in one way or another, but still we must act. In most cases, a proper judgment can be formed later on, although some elements of thought will always remain merely as conceivable and will never come up for verification. These, too, are important and pragmatically necessary stages of our thought. They are products of our faculty of imagination that provides cohesion in mediating sense perception, abstract thought, and agency. Fictions are agency-affording—they fabricate connecting tissue between the world and us, and between us and other agents. Fictions' constitutive way of relating us to the world involves the mediation of sense perception, thought, and agency, and the setting up of deontic relations through constitutive declarations. These two interlinked components lead to a structural explanation of the connections between language and fictions. Possibilities for agency arise for us as paths toward the intentional manipulation of our environment; these can be symptomatically or symbolically charged with meaning such that we can understand them to afford different agential responses. The second kind of meaning enters us into the realm of shared intentionality—where we share in others' and they in our intentionality. If we regard their intentions as more than mere symptoms, but are communicatively compelled to assist them or get assistance from them in what we try to achieve, the possibilities of our agency become deontically enhanced.[3] Fictions facilitate the perception of permanence and contingency in order that we can influence the contingent circumstance in which we find ourselves and in order that our intentions can span past, present, and future. Fictions tie this to our collective shaping of the world through agreement and symbolic representation which can only be realized linguistically. The realm of linguistic rights in education is then that which guarantees the individualized access to such collective agency. This chapter argues for fictions as an important component of knowing the world. Fictions are tied in with a pragmatic notion of knowledge as action-guiding.

We insist that the present educational focus on science, technology, engineering, and mathematics must be amended to include arts because only the arts (liberally construed) are capable of inserting an understanding of agency into the framework of disciplines which meaningfully order the curriculum. Other contributions to this volume point out that STEM is inaccessible without a linguistic and cultural media-

[1]Consider also Pirmin Stekeler-Weithofer's remarks about the shortfalls of an education which is too 'provincial' and forgets the horizon of ideas.

[2]See Friedrich Kambartel's illuminating essay on, 'Gelassenheit' (composure) and the rational treatment of that which is agentially unavailable.

[3]Understanding these structures of rights and obligations requires us to understand that things can take on meaning outside of their sheer materiality because they are counted-as something. When 'counting-as' is communicated, it is the directive to regard some A as-if it were B. Where imagination provides permanence and contingency with regard to 'brute' (billiard-ball) causation, in the case of 'deontic' causation (or constitution) it provides an understanding of status function declarations [as Searle describes them (in Searle, 1995 and 2010)].

tion—indeed, I believe they would become meaningless. There are various arguments that lead to this same conclusion, and they all have to do with the cultural background against which any understanding has to be established. The cultural background is that which underlies our intentional (and rule-governed) activities. It is the biological makeup shaped in a cultural tradition and formed into an individual life. One way of expressing this point is the observation that STEM without arts and meaning can be reduced to purely formal manipulation of information, something which computers do better than humans. However, education should focus on what makes humans special, what their particular humanity allows them to do. This is the most fundamental human right present in education. Another way of expressing this is to admit that a knowledge of agency—knowing what is up to me as an agent and knowing what is beyond my control, but also knowing that we constitute meaning together and that this meaning is available for my contribution—is the key to human flourishing.

The task of an investigation into the *foundation* of the educational curriculum is twofold—it comprises a historical and a systematic concern. In the first instance, a foundational investigation must explore aspects of the historical development of the current curriculum in educational institutions, and in schools in particular. By doing so, one can account for significant changes and shifts in an understanding of the disciplines as well as their boundaries and importance. The idea of transforming STEM into STEAM relies on such a critical understanding of the curriculum including notions of how it needs to be amended. In the second instance, and this is central to a reform of the current *status quo* in educational institutions, one has to keep in mind the most basic aim of the curriculum—human flourishing (or eudaimonia). Therefore, the second task is to identify what is foundational for human flourishing (implemented in education). There are basic (human) rights involved in education, and we need to identify those as the foundation of any institutional educational program. My contribution to this volume will be on this second systematic task. The overall aim is to work toward a clarification of the terms of the discussion, so that the basic eudaimonic aim of institutional education can stand at the center of our attention.

This chapter takes as its starting point the value of fictions as epistemic tools. Fictions afford us insights into the scope of our influence as agents—they help us understand what is tangible for us and how we make sense of the world. The part of our world that we shape and structure as agents is collective and linguistic. An understanding of agency needs to be implemented therefore as the foundation of linguistic rights, and it is crucial in educational contexts where the key to the eudaimonic aim of the institution is to communicate an understanding of agency.[4]

What do human rights to or in education entail? The term ‘human right’ is itself a disputed one. For the sake of brevity, I will define it here simply as a duty borne by society with respect to all individuals, the purpose of which is to assist the individuals in meeting their most basic aim—i.e., to facilitate individual life in community. Most generally, this human right in the context of education involves the institu-

[4]This is what Kant has in mind with his classical formulation of Aufklärung: ‘sapere aude’—dare to know, and it is up to the educational institution to prepare students for such daring.

tion providing (and the student having) access to a proper understanding of agency. Understanding agency means understanding how the world works, what constitutes reality and how we (or I as an individual) can effect changes in it. The curriculum refers to the totality of a student's experiences in an institution; this totality is then divided into subjects with the aim of ordering education. But what is this ordering based on? The order traditionally groups according to contents, methods, and values. From the outset, I would like to emphasize that the order flows out of the institutional reality, which the institution represents and which with Castoriadis we might call 'the Imaginary' (Castoriadis, 1997).

Other than focusing on the procedure of organizing the curriculum—a question which some of the other chapters in this book already address, this contribution will focus on the foundations of the curriculum. That is, I will not discuss identifying learning needs, formulating objectives, selecting contents, and discussing the organization of learning experiences, but instead I will put forth and defend the main thesis that in order for linguistic rights to be realized in education, human flourishing (eudaimonia) must be the aim of the institution in question. The goal of the curriculum overall is to facilitate an understanding of agency. This understanding of agency constitutes the foundation of further linguistic rights, such as free expression in a chosen language.

The chapter has five sections. In Sect. 1, I outline the status quo of the current discourse on fictions. In Sects. 2 (on Kendall Walton) and 3 (on Hans Vaihinger), I consider central aspects of fictions from classical theories and outline my own understanding of fictions as heuristic tools. In Sect. 4, I discuss possible objections against this proposal, and in Sect. 5, I summarize the epistemic point of fictions.

An appropriate understanding of agency is important for human flourishing and should be a central goal of education. To this effect, one of the first proposals is to highlight the importance of different heuristic strategies, which facilitate knowledge of the role of language for us as agents.[5] The present volume gives a great number of examples and demonstrates convincingly the pragmatic relevance of such heuristic tools for a STEAM approach to education. I devote the bulk of this chapter to show how fictions are essential to learning in contrast to a mainstream view, which holds them to be epistemically irrelevant. Fictions serve as a good example in an argument for STEAM: A systematic investigation into the role of fictions for knowing the world (their epistemic function) reveals their pragmatic relevance (their action-guiding purpose). In addition to the concrete and local application of fictions to learning contexts, the investigation shows how fictions are pragmatically and epistemically relevant *in general* because they help us understand agency.

[5]The works of John Searle, especially The Construction of Social Reality' and Making the Social World' which develop out of his earlier language philosophical writings, are groundbreaking in their explanation of linguistic agency.

The Epistemic Point and Pragmatic Purpose of Fictions

> According to the purely mechanical laws of the psyche these entities<fictions>have an immense practical importance and play an irreplaceable mediating role; without them the zest of understanding is impossible, without them ordering the chaotic materials, without them all higher science is impossible, because they serve to mediate, calculate, prepare; without them, finally, higher morality is impossible. (Hans Vaihinger, The Philosophy of the As-if, 1922, p. 69).

The heuristic importance of fictions for learning has been significantly undervalued in the current discussion of epistemic strategies. Aristotle, but also William of Ockham, thought of 'ficta' as necessary connectors between sense perception and thought (and we see this reflected in the quote from Vaihinger above). However, in time, fictions came to be conceptualized as antithetical to truth and reality. As such, fictions are generally considered to inhibit rather than to enhance knowledge. This development is partly due to a (negative) conception of our faculty of imagination. However, there is also the project of a revisionary history of imagination as the story of its misunderstanding, uncovering reasons from Aristotle to Kant for the neglect of imagination as a primary faculty and its reduction to a mere 'ars combinatoria.' The thoughts presented here on the heuristic value of fiction for learning can be seen as part of this revisionist project.[6] Fictions, I stipulate, can and ought to be seen as relevant for understanding (*Erkenntnis*) in different contexts, be these aesthetic, scientific, religious, or '*lebensweltlich*'—they afford us an insight into the make-up of the linguistic reality we create with others.

The contemporary understanding of fictions as a subject matter of scholarly interest considers 'fiction' primarily as a category of philosophical aesthetics or literary studies, taking into account not the (logical) form, but the proposed subject matter of fictions—make-believe worlds in 'works of fiction.'[7] Commonly today, *fictionality* is often regarded as a quality of texts. Furthermore, it is understood as a property of only a certain genre of texts: (literary) fictions. This focus has invited thoughts on how fictions relate to historical accounts of events or to history as a discipline and has resulted in demands that there be norms or indicators by which delineating fictional texts or aspects of texts from true assertions would be possible.[8] However, the scope of fictions is actually far broader. For our purposes, the debate focusing on fictions in aesthetics pertains to the category of fiction in education as a result of its recognition of 'fictionality' as a particular property of conscious intentional representation. Discussing fiction in the context of aesthetics often focuses on the world-making aspect of fictions.[9] In an attempt to emancipate fictional expressions from statement-making, this discourse deemphasizes fiction as a subject matter for

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[6]This is an endeavor advanced, for example, by Cornelius Castoriadis (Castoriadis, 1997), but also by Wolfgang Iser, and others.

[7]Taking scientific modeling to be analogous to make-believe is an application of this analysis. Compare Frigg (2010).

[8]For example in the debate surrounding 'Hayden White's, Metahistory'.

[9]Danto's approach shows this, but also Walton's take on mimesis as make-believe.

epistemology in order to free it from the burden of an epistemic task.[10] In contrast, this chapter argues that fictions *should* be understood through the lens of epistemology as a heuristic means for us. In epistemology, we can describe the role of imagination in the process of cognizing the world and can present fictions as a relevant tool for the philosophy of science and for strategies of knowledge acquisition, for example in STEM education.

The commonly accepted view that truth in fiction is not genuine truth might prevent some of us from accepting the role of fiction in education. If fictions are ‘consciously false’ (as proposed by Hans Vaihinger), then they cannot contribute to the knowledge of truth; if their relation to the state of affairs they represent is to be labeled ‘true,’ then, by definition, they are not fictions anymore. Recently, philosophy of science has again tried to make fictions part of an explanation of how science and knowledge in science works. This line of argument is taken up here. The goal is to understand fictions as relevant for learning. I first stress the intentional aspect of fiction as a mode of representation by revisiting Walton’s account of model-making and then reformulate some Vaihingerian insights.[11] If Vaihinger is thought to have taxonomized fictions and to have established their importance for scientific reasoning, we must first consider his more systematic insight that fictions are as-if judgments and that ideas have a history of their *givenness* to us.

What unifies the so-called fictions of different origin and application is the structure of the as-if judgment underlying them. Fictions should be understood as a form of judgment in which we consciously suspend veridicality, as Vaihinger puts it in his seminal 1911 book ‘The Philosophy of the As-if’. Vaihinger offers a dynamic and localized concept of truth, which seems to be most promising to others who have used him recently in accounting for model-making in science (Mäki, 1980; Suarez, 2008). This contemporary reading is informed by Vaihinger’s pragmatic, to a degree even pragmatist, approach to the exploration of judgment, and the (logical) tools for judging (Ceynowa, 1993; Bouriau, 2013). Vaihinger takes fictions to be action-guiding. Action-affordance is the ultimate reason for humans to engage in the invention of heuristic fictions.[12] Yet, fictions also have an overarching epistemic merit—they help us heed the call of our ‘logical conscience.’ It is this call of our ‘logical conscience’ and its importance for an understanding of agency, which I seek to bring back to the reader’s attention here.

[10]This train of thought must then reach back as far as Baumgarten and the beginnings of aesthetics as a discipline. Lest our view be too near-sighted, though, it should be acknowledged that Baumgarten tries to delineate different forms of cognizance. We are thus remitted to the realm of epistemology at the conception of disciplinary aesthetics.

[11]Vaihiner and other Neo-Kantians such as Cohen were generally much more inclined toward fiction. American pragmatism is close to their analysis in that the comparison between the value of truth and the value of utility was of central importance in both schools of thought.

[12]This if re-applied adds an interesting dimension to the current aesthetics debate where utility is rarely considered an important property of fictions.

Walton's Account: Fictions as Intentional Representations

In this second section, I will reconstruct Kendall Walton's notion of make-believe in order to understand the intentionality of fictional representation.

At the heart of the debate about mimesis and representation in aesthetic contexts lies the question of intentionality. Is the intention, indeed the very concept of an author, necessary for an understanding of the fictionality of the work in question? Walton's classic contribution to this debate has recently been taken up by philosophers of science.[13] Walton locates fiction-making on the side of the audience. Fiction-making is, according to Walton, a function of the reception of an object—a question of regarding something in a certain, make-believe way. Fictionality lies in the eye of the beholder.[14]

This chapter construes fictions in a broad sense as forms of representation in which we consciously suspend veridicality. Today, fictionality is regarded mainly as a property of certain texts—fiction is literary fiction, a kind of literature as distinguished from 'non-fiction.' This demand is central to the debate about authorship and the relevance of an author's intentionality for the understanding of a text or artwork in aesthetics. However, the important insight for an incorporation of fictions as heuristic tools into STEM education stems from the focus on fictions in aesthetics and the recognition of 'fictionality' as a particular property of conscious intentional representations.

A comparison of different domains of fiction brings out the non-descriptive nature of some parts of representational strategies of speakers, as well as thinkers. Mental representations and speech acts correspond to each other in terms of their 'direction of fit.' They are either descriptive and are said to have a mind-to-world direction of fit or are directives expressing an intention with a world-to-mind direction of fit. A description, if achieving a fit, can be labeled 'true.' A directive, if achieving a fit, can be labeled successful, fulfilled, or obeyed. Fictions as mental representations can be understood as representational tools of a constitutive way of relating to the world—as representational they are descriptive, as constitutive they are directive, and the corresponding speech act of this kind of mental operation is the declaration. Fictions as part of a thinker's representational strategy are as-if judgments, as part of a speaker's strategy they are propositions of as-if judgments. Fictions are representational tools for a constitutive way of relating to the world and are thus characterized by a *double* direction of fit.[15]

The idea of 'direction of fit' applies to both a theory of intentionality and speech acts. In analytical language philosophy, Searle, for example, maintains that make-believe is parasitic on descriptive accounts of the world, formulated in statements. Statements, on this view, come before fictions. It must be said, however, that a

[13]Frigg (2010).

[14]Walton (1993).

[15]Anscombe gives the first description of the direction of fit with her example of the man in the supermarket and the detective following the shopper; see Anscombe (1957). The distinction is recently used by Searle in his Construction of Social Reality; see Searle (1995).

speaker's portrayal of a fictional world will often be very useful in directing a listener to look at the world in a certain way. As such, it would be incorrect to judge an act of storytelling as a purposefully false description of a state of affairs, presupposing merely a mind-to-world direction of fit. Rather, storytelling and fictions also have a world-to-mind direction of fit. If we amend our understanding of fictions in this way, we will see that not only is there an analogy between fictions in aesthetics and models in science, but realize how fictions are kinds of mental representations which are arbitrary, normative, and useful.

Roman Frigg has recently proposed to understand model-making in science as pretend play. In his analysis of pretend play, he largely follows Walton's original proposal. Walton's theory and Frigg's adaptation of it to science constitute a global approach to fictions. I take a look at this global approach because it seeks to highlight the importance of fiction as a potential heuristic strategy. Walton describes us as participants in games of make-believe in which we use any object around us as a 'prop' in entertaining pretend-activities and—thoughts ('I see a castle in the clouds'). If more than one person is involved, there are rules of generating such make-believe, which we follow together. The source of fictionality neither lies in the object itself, nor in the author's intention. Walton's theory instead promotes a user-based understanding of fictionality.[16]

Especially with science in mind, some aspects of Walton's theory are intuitively appealing in that they avoid difficulties resulting from disregarding author-intentions in texts. Science does not seem authored in the same way that literature (traditionally) is and it is conceivable that scientists think (and sometimes share thoughts) about their subject in something we can describe as an as-if mode. Frigg stresses as a positive aspect of Walton's model that it does not involve any obscure metaphysical commitments and does not pose additional fictional objects. Frigg points to the difficulty of determining the constitutive pretend-play rules for model-making. In adapting Walton for a model-making account, the similarities but also dissimilarities of fiction and games need to be taken seriously. It is not clear whether science is really a situation of play. If we assume that as-if-judgments (as a way of accounting for the pretend aspect) underlie fictions, we find their logical structure to be a basic mental operation. Not an interpersonal game scenario, but a linguistic aspect to fiction is crucial. As-if-structures underlie games, but they apply to a far wider range of mental operations undertaken by humans that are not all suitably described as pretend *play*. That scientists have certain ways of looking at their research and advancing it by making such as-if-judgments, thus entertaining the mental operation of fictions does not require that they are playing in doing so. The question whether contexts of learning are situations of play would merit some further discussion. I take it that a situation of teaching is a situation which presents reality in an as-if-mode.

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[16]Iser's emphasis on the anthropological constant of staging, of fictions (and especially literary fictions) as part of a 'production' and his concept of a game movement of constant oscillation of play and dissolution of play through which we express and understand something about human nature are not dissimilar to Walton's ideas.

Shifting the focus toward the 'pretend' aspect in terms of its logical form, Walton's account of 'mimesis as make-believe' enables us to see that intentionality occurs on both sides of the equation. Speakers intentionally employ the fictional mode in strategies of communication, on the one hand, while on the other, audiences also generate fictions. Fictionality on the side of an audience's reception becomes part of the act of understanding and can be seen as a mode of understanding. Walton's model can be criticized for its single-minded account of fiction-making where it can be appreciated only as a function of the *reception* of a text, work of art, object, or situation. Yet, the insight that understanding can occur in the mode of fictionality has far-ranging consequences that extend to the question of understanding in general. Understanding something as meaningful transforms any sign or symptom into a non-natural sign—for speakers, audiences, and thinkers generally. Fiction-making is, accordingly, a mental act of thinkers, in general, employed in the understanding or judging of situations.

We will now explore some details of Vaihinger's account presenting fictions as a form of judgment. Walton's take on 'mimesis as make-believe' relates thematically to the work of Hans Vaihinger on as-if-judgments. This 'secret of all fictions,' the unifying underlying structure of all so-called heuristic fictions, is the as-if judgment. However, if fictions are defined as as-if judgments, which purposefully and consciously suspend veridicality, how can they be relevant with regards to a theory of science, or knowledge and truth, in general? Vaihinger's answer, as we will see in the next section, is pragmatic. Fictions are auxiliary tools. Concrete fictions are voluntary conscious suspensions of judgment, and the employment of self-contradictory assumptions follows pragmatic considerations. Fictions are used because they are useful, and despite the fact that they are 'false.' The notion of 'falsity' in Vaihinger relates to a double framework of understanding fictions as logical tools, on the one hand, and in a general explanation of their evolutionary functionality, on the other. It is our 'logical conscience,' which brings us to a realization of the representational nature of the fictions. It is this insight into the representational nature of fictions, which I reconstruct here with Walton and Vaihinger, and apply in an analysis of our understanding of agency.

Vaihinger's Account: As-if as a Form of Judgment

Vaihinger asks himself: How can we employ conscious falsehoods, i.e., fictions, in our explanations of the world and still get a useful result? We can reconstruct Vaihinger's argument on fictions by looking at his analysis of the as-if as a modality of judgment along with his numerous examples illustrating their ubiquitous use. Beyond giving a taxonomy of (heuristic) fictions, mostly in scientific discourse,[17] I consider Vaihinger's work to be much more systematic in nature, expanding to account for the function of our knowledge and our actions in the world.

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[17] Iser criticizes Vaihinger's account as a florilegium of fictions' (Iser, 1991, 256).

For Hans Vaihinger fictions are best understood as a particular way of suspending judgment of the form ‘A as-if B,’ thereby telling us something about the judger. In using this form (‘A as-if B’), one resigns the veridicality-standard that attaches to primary judgments in order to put together two contradicting aspects of perception and conceptual scheme for the sake of practical use. If she herself comes to understand this modality of judgment in light of an analysis of the logical tools available to her, but also in light of the insights of an ‘evolutionary epistemology,’ she answers to the call of her ‘logical conscience.’ This allows her to mediate the explanatory realms of evolution and logic, while still retaining a non-relativistic notion of truth, one that is nonetheless continuous with a functional (evolutionary) explanation. The focus of such an explanation is pragmatic, i.e., lies in explaining the agency-affordance of all behaviors and practices. Understanding ‘fictive judgments’ as a transitional, purposeful, arbitrary suspension of judgment, we can see how fictions come to be characterized by Vaihinger as preliminary, conscious, contradictory, and action-guiding. Judging, and its expression in speech and text, has the component of a ‘modality.’ ‘Fictive’ is one such possible modality describing the judger’s explicit suspension of veridicality for the sake of practical or applied use.

The difference between hypothesis and fiction shows this well. It is a functional difference: A hypothesis, ‘A may be B,’ postpones judgment to a later point in time. ‘A as-if B’ is neither true, nor false. The fictive judgment ‘A as-if B’ does not qualify for verification in the first place. It just isn’t the type of thought that could be verified. According to Vaihinger’s distinction, a hypothesis has to be verifiable (*wahrheitsfähig*), while a fiction has to be conceivable (*denkmöglich*).

According to Vaihinger, a thinker always takes up a stance vis-à-vis her idea. In doing so, she uses different ‘modalities.’ Vaihinger’s ‘*Gesetz der Ideenverschiebung*’ (law of the devolution of ideas) identifies three stages in the life cycle of an idea: dogmatic, hypothetical, and the as-if stage. Each denotes the way in which a thinker conceives of her idea as dogma, hypothesis or fiction. Each of these conceptions depends on her judging ‘A is B,’ ‘A may be B,’ or ‘A as-if B.’

Vaihinger introduces two frames in which terms like ‘truth’ and ‘fiction’ can be explained: the logician’s frame in which logical mental tools for ordering and understanding the world accessible through sense data are taxonomized, and a second frame of someone whom we would today call the evolutionary epistemologist who is theorizing cognition as a feature of biological evolution. In the former frame, fictions appear as one heuristic strategy or tool to be differentiated from other logical tools—this is the frame which we use when we speak of assertoric versus non-assertoric (or problematic) judgments. In contrast, there is also the latter frame, in which all thought appears as the psyche’s reaction to and coping with environmental stimuli. The life cycle of an idea as dogma, hypothesis, or fiction is explained as the psyche’s attempt at stress–depletion where a fiction provides the most tension and a dogma the least, thus making it the case that the psyche tends toward rephrasing all fictions as dogmas.

It is our ‘logical conscience’ that anchors a term like ‘truth’ not only in the former, but also in the latter frame. Our ‘logical conscience’ links this purely biological explanation to the logician’s way of understanding the life of the mind in which these terms and their roles appear in relation to each other and to our other heuristic practices. Both frames, then, necessarily inform each other. They do so because our ‘logical conscience’ demands it.[18] The merits of a double frame type of explanation are (i) its continuous functional explanation of the life of the mind—continuous with evolution in the realm of biology, functional in that it places a main importance on agency-affordance, (ii) its differentiation of logical tools and their use in heuristic practices such as science which allows for an assessment of theories according to their different elements, and (iii) its built-in function of revision and critique, a dynamization of our process of knowing, accounting for different techniques, and transitions between judgments according to the overall function of ‘fitness’ of the organism in an environment. It is, finally, the binocular view through the evolutionary epistemologist’s and logician’s lenses through which we access a complete picture of ourselves that informs our ‘logical conscience.’

A Zest for Understanding: Fictions as Mediators of Science and Morality

Since Kant’s first expression of the antinomy of moral agency versus empirical science regarding the question of the determinism of events, ethics, as a realm of causation through free agency, and science, as the investigation of determined natural causation, have been conceived of as essentially separated. A Vaihingerian line of argument can re-establish a key connection:

Vaihinger notes (as in the quote above) that without the mediation of fictions, there would be no way of ordering and organizing the multitude of sense impressions, that without them there would be no ‘zest for understanding,’ that neither ‘higher forms of ethical life,’ nor ‘higher forms of science’ would be possible. The link between fictions as concrete historical ideas and fictions as expressing a stance toward judgment connects ethical life with the practices of science in their ‘higher forms.’

Understanding concrete items of thought in historical theories as fictions and pointing to the potential origin of some ideas as fictions which only later became dogmatic, such as mythology or aspects of religious faith, for example, lets us see them as conceptual aids which not only can become obsolete, but are also subject to revision. The ‘law of the devolution of ideas’ posits that ideas themselves have a history of *givenness* to us. The assumption of an advancement of our ‘logical conscience’ explains how this history occurs. It is the ‘logical consciousness’ which

[18]Vaihinger’s fascination with an evolutionary explanation coupled with his inclusion of the contemporaneous findings of a physiological psychology (such as Horwicz’ description of the reflex arc that Vaihinger processes into his idea of tension releases in the psyche) might seem outmoded to us. The argumentation is one frequently found as a theme in works at the time, such as Nietzsche’s critiques of truth as illusion, although Nietzsche is more interested in dismantling the logician’s frame than Vaihinger. Whereas Nietzsche aims at a general relativization of the terms ‘truth’ and ‘knowledge’, Vaihinger attempts to bridge the gap between truth as correspondence and truth as an evolutionary ‘illusion’ by giving the double frame explanation.

leads to the (re)-recognition of dogmatically held ideas as fictions and to insights into the evolutionary nature and function of thought and logical thinking tools. The two frames of understanding, the logician's and the epistemologist's, are interventions by our 'logical conscience.' They force upon us a recognition of the nature of our heuristics, both in ethical life (including religious belief) and in science, both of which are primarily and ultimately agency-affording. The 'higher forms' of ethics and science are a mode of engaging with ethics, religion, art, or science which is self-aware of both frames of interpretation applying to our mental operations: the logician's and the evolutionary epistemologist's frame.

The most relevant question for an agent is not primarily one of epistemic access to information, but rather the question of the exertion of control over events and circumstances.[19] For her to become an agent, the knower has to be able to tell apart the aspects of the world that are causally determined without her input from those available to her in agential realms that are collectively constituted. Vaihinger's 'logical conscience' guarantees this necessary detachment and awareness for the agent. Concrete fictions anchor her in terms of permanence and contingency and orient her in the here and now, which depends on a timeline of past, present, and future. They show her in which ways she can act, both in terms of 'brute' and 'deontic' causation.[20] As-if-judgments are responsible for the higher forms of science and ethics because they concern the two key aspects of agency: 'permanent contingency' and 'linguistic constitution.' Permanent contingency is the perception of a continuity in the contingent cultural circumstance in which we find ourselves and the perception of possibility of effectively acting in it. The linguistic constitution involves the realization that the most relevant aspects of the world in which we can be effective as agents is constituted in a linguistic collective.

Both of these aspects together make up a knowledge of the horizon of (human) agency, that is the framework within which agency is possible. Knowing oneself to be an agent and how to be one is the central tenet of an educational agenda which empowers the individual.

What Fictions Teach Us About Agency

In this section, I will first address some objections against the proposed understanding of fictions and secondly summarize their epistemic point—that they contribute to an understanding of agency.[21] I will then argue for the realization of human and, specifically, linguistic rights in education. Understanding agency is, as I have claimed,

[19]This agrees with a certain understanding of Pragmatism. Compare Godfrey-Smith's reading of Dewey.

[20]See Searle (1995).

[21]The account I give of fictions and their contribution to agency does not specify what concrete fictions are used by a thinker. Vaihinger's point about fictions is that we change them according to our pragmatic (and epistemic) needs and that we discard them once they have fulfilled their function. Of course, there could be concrete fictions used in education which are not helpful, but

the human right present in the educational context; this entails linguistic rights, in particular, because agency is essentially constituted through language.

I should attempt to settle worries that a neo-Vaihingerian ‘fictionalist’ view might proliferate models and thus harbor anti-realist-tendencies. This doubt about non-factual aspects of knowledge, I believe, contributed to the concept of an educational project focusing on facts and practical applicability of sciences, leaving out arts (and fictions) as epistemically irrelevant. By anchoring fiction and truth in the same discourse, thus making it the case that a contentious notion of ‘elegance’ (over truth) be not the only standard for the adequacy and use of models, we can hopefully settle some of this worry. The pragmatist orientation of a neo-Vaihingerian proposal prevents us from inventing ‘models-for-models’-sake’ as the question of heuristic utility will always be tied back to agency-affordance. *Frustra fit per plura quod potest fieri per pauciora*—Ockham’s principle (known as his razor) has much to do with the fact that if you admit at the outset that fictions are a key aspect of understanding the world, you at the same time must prevent the unchecked proliferation of such fictions through models, concepts, ideals, hypotheses, etc. Since they are not bound causally by the sense data that are their cause, but instead can be invented and reinvented ‘arbitrarily’ (and at times conventionally), it is necessary to introduce another way of pruning them.

The fact that fictions can be replaced by other fictions at will or according to a concept of utility or for pragmatic considerations makes them ideal candidates for the development of new ways of thinking and creative solution-seeking. Vaihinger and Nietzsche refer to this quality as ‘elegance in style,’ or ‘simplicity in explanation.’ Vaihinger believes that those fictions which are the most straightforward, elegant, and simple will win out in the end (Vaihinger, 1922, p. 11). This is not a problem for truth-seekers, though, and it does not mean that we have no other standard but ‘elegance’ for our solutions. Vaihinger’s view does not support a ‘fictions for fictions’ sake’ doctrine. Fictions are constrained by how useful they are for agency, i.e., our form of being in the world. If they prove to be useless, they are discarded. The use meant here is one inherent in the heuristic aspect of the fiction for an application to reality. It is not, for example, the abuse of a scientist of the model for her own (academic) profiling or for the sake of creating an elegant mathematical solution. The Vaihingerian stresses that fictions as such are not to be kept forever, but that they are just practical means for reaching an end—they are *practically* useful. They open up space to create. It is helpful to think of instructions governing the use of fictions—something like a user guide for fictions which outlines how fictions have to be adjusted to real conditions and have to be omitted once the practical purpose is met. We would like to understand why fictions can be useful for thought in getting to some result, not necessarily governed by truth as a benchmark for validation. For such a functional account, we assume that all thought (and speech) serves a function, and that truth is not the only or last goal we pursue.

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rather hindering to a student’s understanding; some of those fictions might be labeled, ideological, bearing a negative connotation.

Historically, science (or, at least, the *idea* of science), emancipated from the task of instant action-affordance, can be seen as foundational research. This structure is much like art for art's sake. It stretches the boundaries of possible methods, or, as in the case of art, the understanding of the medium or practice is enhanced, generating value by providing a general knowledge of how the world is. However, this does not place science or art beyond the question of utility generally. The fundamental aim of science and art is agency-affordance: that the agent may be better able to manipulate her environment. In order to manipulate, she has to understand. Understanding happens only through mediation of concepts and with a pragmatic aim in view.

The functionalist might rephrase her question: What is the function behind a seemingly purposefully inoperable endeavor (Art for Art's sake, foundational research)? As Vaihinger notes, only a misconstrual of science, but also an overly embellished methodology (such as mathematical modeling in economics) lead to disregarding functionality, ceasing to yield heuristic results, and ultimately will causing us to discard the theory. The thinker in the as-if-stance realizes the functional foundation of representations and desists from taking the representation for the thing represented.

Even if humanity is on a path to building ever better theories which involve less and less conscious falsehoods (something Vaihinger believed), he still points to the inevitability and crucial role of conscious falsehoods for an advancement of knowledge. Not only are fictions aids along the way to truth, but they are also permanent logical tools. Whereas concrete fictions will naturally keep falling away and be replaced, our methods of thinking always involve as-if-judgments. As answers to the call of our 'logical conscience,' truth and fiction may play complementary roles in our discourse. Vaihinger describes the mental act of the creation of a fiction as the psyche's aim at reducing tensions. Dogma is the state of an idea that provides the least tension or friction between the world and mental representation. A slipping into dogma must actively be avoided if we are to maintain a critical stance vis-à-vis the world. It is the as-if-structure in fictive judgments that provides—like a volatile chemical bond—the most friction for such an active resistance and thus best represents our 'logical conscience.'[22] Although the psyche seeks to deplete tensions which build up once it becomes evident that world and '*Weltbild*' fall apart, the stance furthest from dogma—the as-if-stance, reflects our logical conscience best. Our logical conscience calls to our minds that world and model are not the same, but that the latter is a representation of the former, that representations have a pragmatic aim and thus a voluntative aspect, that they depend on an observer. The observer-dependence ties them closely to the part of the world which we create linguistically—those rights and obligations which can only exist because we believe them to be in existence and we collectively agree to honor them and individually do so.

[22] Huw Price describes truth as causing a similar friction (Price, 2003). According to Price, only the norm of truth gives disagreement an immediate normative character. Truth provides the necessary friction for participants in a discourse (in a pool of knowers) to keep them in line and to force them to check their speech (and thoughts) against a background of facticity. No dialogue would occur governed by a lesser norm. That *all* truth might be *fiction* (an implication Price does not deny) does not follow for a neo-Vaihingerian view.

'Truth' and 'fiction,' along with a description of different modalities of judgment, belong to the same, rather than to rivaling discourses—they concern an understanding how we act in the world.

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Part II
Technology in Design Curriculum, Engineering in STEAM Pedagogy and the Arts

Chapter 6
STEAM Education: Why Learn Design Thinking?

Alma Leora Culén and Andrea Alessandro Gasparini

Abstract This chapter will discuss effects of using the design thinking approach when developing STEAM curriculum. The interesting perspective in this context is the synergies coming from the design thinking cycle (Brown, 2008) as it addresses directly the art and design in the STEAM context. The strength of the design thinking approach is the possibility to tackle complex and ill-defined problems (Brown & Wyatt, 2010), ranging from business to ecological and social context (Stolterman, 2008). The problems of this type are usually named wicked, as they have no definitive solution (Buchanan, 1992).

Introduction

Traditionally, good education has been tightly coupled with teaching science, technology, engineering, and math—the STEM subjects, often separately. The STEM education has been discussed over the last two decades widely. The novelty of the approach rests on the idea of integrated learning of mathematics, science, engineering, and technology. Hom defines STEM as follows: "STEM is a curriculum based on the idea of educating students in four specific disciplines—science, technology, engineering, and mathematics—in an interdisciplinary and applied approach. Rather than teach the four disciplines as separate and discrete subjects, STEM integrates them into a cohesive learning paradigm based on real-world applications" (Hom, 2014).

So far, the promise of the STEM education to provide a different learning model based on "real-world applications" has largely remained unfulfilled in practice (Sanders, 2008). As Sanders argues, grounded on historical reasons, each of the educational fields has "monopolized the landscape for a century" and still does so,

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despite STEM. However, the emerging successor model of education, science, technology, engineering, art, and mathematics (STEAM) is now slowly gaining traction, promising to tackle real-world problems more effectively through creativity and designerly ways of knowing and thinking.[1] STEAM reflects the necessity to address learning based on real, complex, interdependent, dynamically changing problems that are often referred to as wicked (Quigley & Herro, 2016), and for which science and technology alone have not, and are not likely to, provide solutions. The inclusion of art, and as we argue in this chapter, much more importantly, the inclusion of design to the STEM (Yakman & Lee, 2012), is aiming to transform the education through creativity and design in the twenty-first century, just like science and technology did in the last one. Yakman is frequently credited with the formalization of the STEAM concept and its implementation in South Korean schools, where the government adopted STEAM as a national education initiative. STEAM is expected to be a major catalyst to innovation, discoveries, and knowledge advancements. These expectations are well aligned with the design thinking (DT), a design-led approach to real-life problem-solving. It is grounded on human-centeredness, and creative, holistic, and multidisciplinary thinking. DT has demonstrated the ability to tackle complex issues that the world is facing today, such as climate change, poverty, education, water access, or health on the one hand (Kolko & Austin Center for Design, 2012), and innovation on the other (Brown, 2008; Brown & Wyatt, 2010).

In this chapter, we present our view on how DT could support the implementation of STEAM education. We used it over the past few years in teaching human—computer interaction within a computer science department at the faculty of natural sciences at the University of Oslo, where design is not part of the curriculum (Culén, 2015; Culén & Følstad, 2015; Culén, Mainsah, & Finken, 2014; Finken, Culen, & Gasparini, 2014). We found that DT helped students to think creatively, critically, increased their ability to articulate and communicate ideas to others, and broadened exploration of the design context, along with other benefits. Design as a discipline remained outside the scope of the curriculum in human–computer interaction. However, in course projects where DT was applied, it was integrated with other STEM subjects and yielded innovative and interesting perspectives, concepts, prototypes, and solutions. In addition to experiences with classroom projects, we used DT in a long-term research project related to innovation in the academic library, where the library employees, as non-designers, learned and integrated DT with their everyday practices successfully.

Based on findings from these two contexts, we explore further how to incorporate DT also in other learning contexts. We argue that some of the lessons learned can be transferred to STEAM education and support both emergence of new knowledge and learning, and hands-on innovation processes that offer a different kind of learning such as learning to work in a multidisciplinary manner, building teamwork competencies as a way to solve problems together, learning from each other, learning by making tangible prototypes of ideas and concepts, reflecting on design and articu-

[1] Refers to things to know, ways of knowing them, and ways of finding out about them grounded in design as a discipline (Cross, 2006).

lation of proposal. Benefits of such learning surpass the benefits of only increasing the use of creativity in science, technology, and engineering education (Sochacka, Guyotte, Walther, & Kellam, 2013).

The chapter does not address explicitly the main theme of the book, where promoting the language as human rights through STEAM education is in focus. However, dialogical spaces described in this chapter come close to this theme. They help establish a common language required to inquire into real-world problems when using the STEAM approach. Rather than human rights, dialogical spaces provide a basis for equal rights to participate in shaping, discussing, and articulating possible solutions. Through rapid learning and prototyping, in combination with an open dialogue utilizing the commonly shaped, thus familiar and understandable project language, the members of the problem-solving team become truly capable of exercising these equal rights. Naturally, when a problem calls for considering human rights explicitly, a dialogical space is used to discuss them, allowing for deeper understandings and considerations of alternate futures based on proposed solutions, and their relation to human rights.

The chapter is structured as follows: In the next section, we provide a brief overview of DT approach to real-life problem-solving. Further, aspects of DT that we view as central for STEAM education to deliver integrated, experiential learning are highlighted. This section also includes a brief overview of previous research on an innovation-based learning and its integration with experiential learning. The fourth section describes dialogical spaces as one of the most important prerequisites for successful implementation of DT in education. Dialogical spaces include communication among team members, articulation of knowledge, values, ideas, intents, and the ability to rigorously scrutinize and synthesize proposals. In addition, the sections address cognitive thinking styles, possible cognitive biases, and ways of mitigating them. We proceed to discuss how to learn DT, in educational settings and in situations where professional designers are not involved. The discussion is based on our experiences in using DT in diverse real-life projects in a context of a course, and a workshop with 17 DT practitioners. Our findings and experiences highlight opportunities that DT holds for STEAM education. Finally, we present the overall discussion and the conclusion, arguing that DT has a great potential to be a powerful engine for STEAM learning and education.

Design Thinking

Over the last decade, design thinking has been in the center of attention also within fields that are traditionally outside of the field of design and design research. A quarter of a century ago, the design theorist, Richard Buchanan stated:

> …, for we have seen design grow from a trade activity to a segmented profession to a field for technical research and to what now should be recognized as a new liberal art of technological culture. It may seem unusual to talk about design as a liberal art, particularly when many people are accustomed to identifying the liberal arts with the traditional 'arts and sciences'

> that are institutionalized in colleges and universities. But the liberal arts are undergoing a revolutionary transformation in twentieth-century culture, and design is one of the areas in which this transformation is strikingly evident (Buchanan, 1992).

Indeed, with the complexity and interconnectivity increasing fast, wicked problems are everywhere, and if the design and designers can tackle them, it is something that everyone should learn how to do. In his book, Lawson tries to do just that—enable anyone to learn how designers think and demystify design processes (Lawson, 2006). Other researchers and practitioners from diverse fields have also joined in the discussion related to how designers think and work, and how to articulate and communicate new knowledge emerging from the practice of making (Cross, 2006; Dalsgaard, 2016; Fallman, 2003; Stolterman, McAtee, Royer, & Thandapani, 2009). At the start of the twenty-first century, the first school emerged that could be viewed as a STEAM school, d.school at Stanford ("d.school", 2017). d.school was not a part of Stanford's formal education, but rather a place for learning and transformational experiences through an interdisciplinary engagement around real-life problems. The school's interdisciplinary mode of working, collaboration with IDEO,[2] and design-led approach have helped create a powerful human-centric methodology for innovation that has successfully integrated expertise from design, technology, social science, engineering, and business (Brown, 2009; Martin, 2009). The teamwork and highly interactive environment that promotes creativity, learning through empathy with users, rapid conceptual prototyping, and abductive thinking showed to be a successful approach to finding novel solutions. Later in this chapter, we reflect over how these can be adopted and learned, even when one does not necessarily think like a designer naturally.

The design thinking approach has been found to promote a systemic, more holistic view of the context in which a problem that needs solving occurs. Often, rather than isolating and fixating on a specific problem and how to solve it correctly, which is a common practice, the DT approach broadens the scope and considers the whole context anew. This is done in an effort to correctly identify the "real," perhaps underlying and hidden, problem to solve rather than the one that was visible and obvious at the start. DT aims to understand the entire system and how different parts affect each other and predict how any particular suggestion affects the whole system.

The DT process is often described by the following phases that the process unfolds through: discovery, interpretation, ideation, experimentation, and evolution; see Fig. 1.

The discovery phase entails, as described, the identification of the right problem to solve. Usually, multiple paths that could lead to a possible solution are explored. A holistic understanding of the context is crucial; thus, this phase utilizes divergent thinking. The importance of this phase should not be underestimated. The questioning and asking the right questions, tightly coupled with the ability to think critically and creatively, are considered to be central aspects of design thinking (Fabun, 1968; Norris, 1985). Little was known about systematic ways, either through theoretical or empirical work, to find right problems to solve (Dillon, 1982) until design thinking

[2] IDEO is a design consultancy that was instrumental in propelling DT. See http://www.ideo.com.

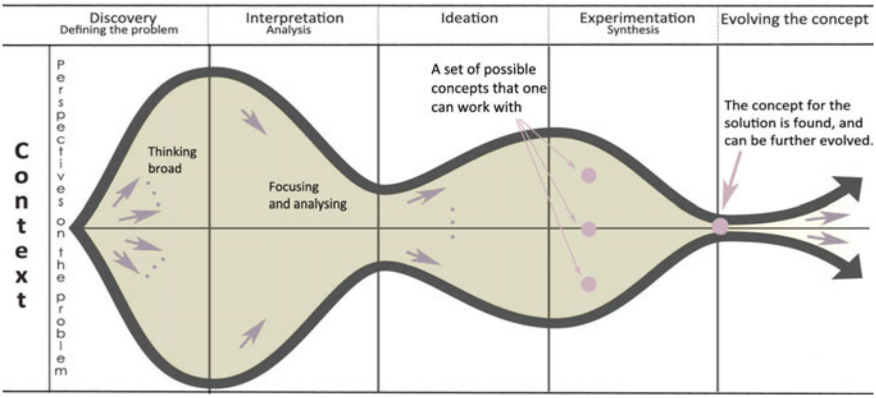

Fig. 1 Design thinking process, as it oscillates between divergent and convergent thinking modes and advances through phases of discovery, interpretation, ideation, experimentation and evolution

emerged and provided an effective way of, at least, having a persistent focus on that goal. With its multidisciplinary teamwork, diverse ways of mapping and visualizing the problem space (Sevaldson, 2011), numerous tools and techniques to facilitate communication and rapid learning, DT ensures that scaffolding for identifying the right questions to ask is in place.

Once the broad picture is outlined, rigorous analysis and convergent thinking are used to interpret and narrow down proposed choices to the ones deemed to have highest potential to yield a good solution. In this phase, meanings and values are also discussed. In the next phase, divergent thinking is used again, to support broad ideation processes, and then convergence toward a more precise definition of a possible solution. This process is carried out iteratively until the final concept that can be evolved further is found. Rapid prototyping, empathy, analysis, and synthesis support this process.

Design Thinking and Education

After the initial enthusiasm for DT in innovation processes, it became clear that DT cannot be a straightforward process. Nussbaum observes:

> From the beginning, the process of Design Thinking was a scaffolding for the real deliverable: creativity. However, in order to appeal to the business culture of process, it was denuded of the mess, the conflict, failure, emotions, and looping circularity that are part and parcel of the creative process. In a few companies, CEOs and managers accepted that mess along with the process and real innovation took place (Nussbaum, 2011).

In short, the core of DT is creativity, often leading to messy and unstructured processes. By framing DT in a particular, procedural way, as is often done in business, the creativity becomes limited, and the main feature of DT, the ability to navigate ambiguity, is lost.

We find that the situation in education is quite similar. That is to say, schools have created practices that aim to avoid creative and messy processes at schools. Working on eliminating the mess, the conflict, the failure, and negative emotions from school environments, gradually, led to learning being denuded of them and forgetting that they all are parts of the creative processes and good learning practices. The main strengths of DT are based on accepting the messiness and uncertainty, learning from failure, intense cooperation, fast learning from others, synthesis, rapid experimentation, the ability to move between the abstract and the concrete, being aware of intentionality and consequences, as well as having the ability to articulate and communicate one's views ("d.school", 2017). These can be considered as a set of desired abilities and competences that can be practiced and learned. Thus, adopting DT may have a huge potential to influence educational settings positively.

Razzouk and Shute state that DT

> can have a positive influence on 21st century education across disciplines because it involves creative thinking in generating solutions for problems. … Thus, to help students succeed in this interconnected, digital world we live in, educators should support students in developing and honing 21st century skills (e.g., Design Thinking, systems thinking, and teamwork skills) that enhance their problem-solving skills (Razzouk & Shute, 2012, p. 331).

If we accept that asking the right questions, seeking holistic understanding of the problem area, and experimenting with alternative possibilities rather than having ready answers are a better option to guide students into an uncharted future, then DT offers a pragmatic, experiential, and constructive way to propose and implement learning that prepares students for such tasks and improves their ability to ask good questions, tackle issues, and come up with innovative solutions that contribute to moving that uncharted future in a good direction. The DT approach encourages students to explore alternatives through divergent thinking and to be able to make choices through convergent thinking. However, its impact on students goes beyond just thinking creatively.

Creativity, the main active ingredient that DT approach offers to education, is something that both scientists and designers need in their work. However, it is cultivated and expressed differently within practices of science and design. According to Owen (2007), creative people tend to work in one of the two ways: by invention (makers) or by discovery (finders). The model adapted from Owen's work (ibid.) and shown in Fig. 2 shows how new knowledge is created within these two basic ways of engaging with the world, and it points to the persistent gap between theory and practice. To this end, complex real-life problems present an opportunity to bridge the gap between the theoretical, discovery-based knowledge and designerly ways of working and thinking through the pragmatic and experiential approach that DT offers.

Some researchers have attempted to formulate integrated models for experiential learning, starting from the groundbreaking model by Kolb (1983). Kolb's model suggests that experiential learning requires self-initiative, an intention to learn and

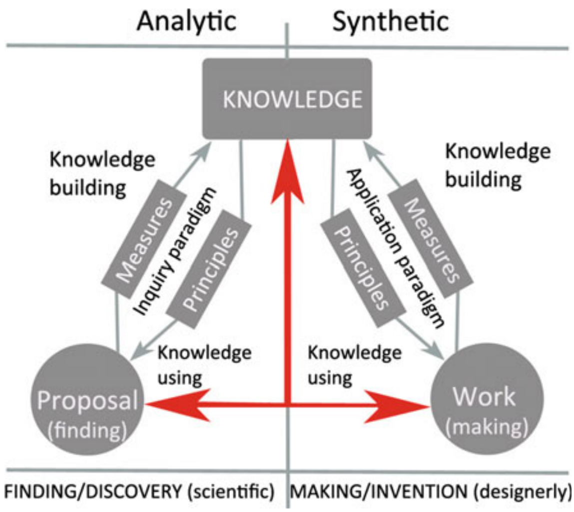

Fig. 2 Adaptation of Owen's model, from (Owen, 2007), of creative domains and knowledge production within them

an active phase of learning. His cycle of experiential learning styles covers concrete experience, reflective observation, abstract conceptualization, and active experimentation. Beckman and Barry present innovation framework adapted from Kolb in Fig. 3, top left (Beckman & Barry, 2007). The experiential learning theory model juxtaposes two approaches to grasping experience (concrete experience and abstract conceptualization) and two approaches to processing and transforming experiences (reflective observations and active experimentation). Observations lead to insights. They, in turn, lead to ideas, some of which lead to a solution of the problem, Fig. 3, bottom left. Finally, Beckman and Barry (ibid.) integrate the two models and present their model of innovation-based learning in Fig. 3, right.

One of the problems arising when talking about creative approaches and innovation to problem-solving, also in the context of STEAM, is related to individual's perception of their own ability to be creative. Often, people think that they do not have the needed creativity to solve problems through either discovery or design. However, Csikszentmihalyi, who has long studied positive experiences and creativity, has found that for many people happiness comes from making new things or making new discoveries (Csikszentmihalyi & Wolfe, 2000; Csikszentmihalyi, 2013). Recently, emotional learning is recognized as important and directly related to the meaning-making process of the individual's direct experience, but also in relation to teamwork (Näykki, Järvelä, Kirschner, & Järvenoja, 2014). Emotional learning is a relatively recent concept, related to the understanding of emotion and intelligence in relation to happiness or success. When processes with teams of learners work well, chances are, for each student, to increase experiences of happiness through creative processes and discovery. Furthermore, team-based creative processes help reduce

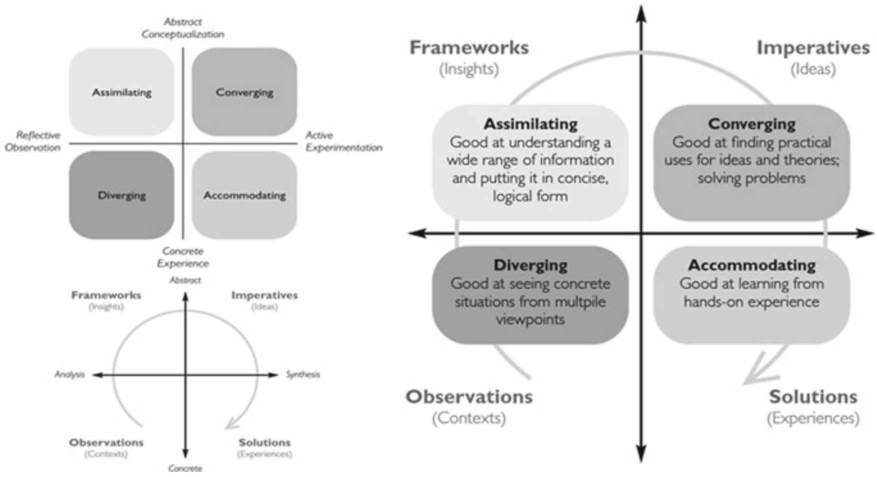

Fig. 3 Beckman and Barry's model that integrates design thinking, innovation, and learning styles (Beckman & Barry, 2007)

potential fears that students may hold about their ability to be creative and contribute in a meaningful way.

The ability to analyze (situations, observations, points of view, etc.) and the ability to synthesize (ideas, pick best parts of diverse solutions and put them forth as a new proposal), as well the ability to shift between the abstract and the concrete, are crucial. The design thinking approach employs four thinking styles, as shown in the upper left corner of the Fig. 3. In addition to divergent and convergent thinking discussed earlier, assimilating and accommodating thinking styles are applied. Assimilation is related to understanding the wide range of information and being able to extract the most relevant information concisely. The accommodation style relates to practical issues at hand that are related to learning from hands-on experiences. The alternation between these thinking styles, especially the divergent and the convergent thinking in different stages of the design thinking process (see Fig. 1), is relevant for how the problem-solving activity evolves. These alternations are recognized as the main constituents of creativity (Beckman & Barry, 2007; Cropley, 2006). Divergent thinking is supported by variety of approaches to gather new perspectives and insights, requiring students to be unconventional, seeing the known things in the new light, combining disparate information, producing multiple answers, shifting perspectives, transforming the known, seeing new possibilities, taking risks, retrieving a broad range of existing knowledge, and associating ideas from remote fields (Cropley, 2006). The willingness to open to a broader understanding of the problem area and get more insights is crucial to produce new or unexpected combinations of the known. Divergent thinking facilitates the process of broad explorations. Divergent thinking is also necessary in another phase of the design thinking approach, the rapid prototyping process. Here too, divergence is needed to think and rethink alternatives when designing different

Table 1 Flaws in cognitive processing and possible relevance for education (adapted from (Liedtka, 2015) to educational settings)

Cognitive bias	Description	Relevance in context of education
Projection bias	Projection of the participants past	Failure to generate novel ideas
Egocentric empathy	Projection of own preferences onto others	Failure to gain insight and see new values
Focusing illusion	Over-focusing onto particular elements	Narrow focus, lack of broadness
Say/do gap	Problem that has to do with what people do versus how they describe it	Prevents accuracy in assessing needs and desires
Hot/cold gap	Decision makers emotion-laden state	Undervaluing or overvaluing ideas
Planning fallacy	Over-optimism	Tendency to imagine rosy future
Hypothesis fallacy	Look for confirmation of hypothesis	Not collecting data that falsifies the hypothesis
Availability bias	Preference for what can be easily imagined	Options that are harder for students to imagine are valued less

prototypes that communicate ideas leading toward possible solutions. Convergent thinking, on the other hand, forces rigor and analysis, as well as synthesis, aiming to recognize what belongs together so that one can combine insights and finally define and formulate one direction to pursue further.

As stated before, DT is an approach made to tackle uncertainty and ambiguity when solving complex problems. In this context, the divergent and convergent thinking bring forth a high level of learning, creativity, and reflectivity for engaged students (Mahmoud-Jouini, Midler, & Silberzahn, 2016).

However, in her article, (Liedtka, 2015), Liedtka addresses how DT methodology might reduce biases that could affect innovation outcomes. We have considered the biases she discussed and tried to see how they were mitigated in the course settings where we used DT. A large overlap was found, and we list relevant biases to students' cognitive processes in Table 1. Our finding, when concerning the ways to mitigate them, is in line with those reported by Liedtka. All the biases listed in Table 1 are diminished or resolved by properties of design thinking: user-centeredness, empathy, deep data collection, good understanding of the context, holistic understanding, and construction of dialogical spaces.

Dialogical Spaces and STEAM Education

The importance of dialog for human activities is universally recognized. Dialog is explicitly addressed in design (Krippendorff, 2006), creativity in education (Csikszentmihalyi & Wolfe, 2000), systems thinking, and emotional learning (Näykki et al., 2014), much along the lines that we use it and discuss in relation to STEAM education. However, in DT, the need to carefully frame spaces in which multiple dialogues can take place is highlighted even more strongly. In multidisciplinary teamwork, there is a need for the team members to communicate, share, exchange, and demonstrate their skills and knowledge, so that they can together engage in solving a problem. DT must enable the creation of dialogical spaces where such exchange is supported, and common understandings created. According to Krippendorff, (Krippendorff, 2006), reaching a common understanding during design thinking processes can be attained in two ways. The first way is for one person to address a group, take a lead, and have a "*monological passage,*" i.e., impart the information to others. Explaining an idea using this approach does not imply a common agreement on that idea, or a common constructed meaning around it. The second way, according to Krippendorff, forwards dialog as the contrasting approach to monological passage.

In our work, we broaden the idea of a dialogue and work with what we call dialogical spaces. They support distinct and parallel dialogues within the same design context. At the start of a problem-solving activity, all different positions, values, and knowledge that any team member holds are invisible to other members. Unless a language is used to express these outwardly or, alternatively, hands to make artefacts expressing these, they would remain hidden for others. Thus, dialogical spaces need to mediate creation of a shared language and facilitate exchange. It has been argued that spoken, visual, and bodily languages are all important to create these shared meanings. Visual representations, such as images, sketches, promote consensus and aid in decision making. Visual representations, which may be seen as the productions of visual languages, are recognized as facilitators of cognition (Karabeg, Akkok, & Kristensen, 2004). The spoken language shapes the problem spaces at hand by using words for ideas, tools, methods, as well as actions. It is important to make the meaning of words within a situated context clear. For example, prototype and prototyping may mean very different things to an interaction designer than to an engineer. The correct meaning of prototype and prototyping needs to be agreed upon, in relation to a particular project. When common meaning is created, it frames the situation for all participants in terms of something that is now familiar and shared. Furthermore, language is different when one speaks with design attitude than when one speaks with decision attitude during problem-solving. Also, team members' values cannot be separated from the language and its use.

Sharing is not enough. Dialogical spaces need to support coexistence of diverse opinions and points of view, at least until a joint decision has been made on the direction of the work. This may be regarded as mutual respect, and safety of a dialogical space, where no team member should feel that their input is undervalued. Usually, teams choose someone to facilitate creation of dialogical space and serve as mediator. These mediators, in particular, need to be aware of problems and pitfalls, such as cognitive biases, and how they can affect the whole process (Rowe, 1987). In projects that use DT, hands-on phase, prototyping is also very important. In this phase, participants may have different levels of skills, but learn fast that no matter where their capabilities are, using prototypes they can communicate effectively. Prototyping itself, thus, also supports the dialogue and contributes to creating a dialogical space in which, through material and tangible means, diverse ideas can be communicated, with minimal possibility of misunderstandings. Redefining and changing the prototype also conveys and reflects back to participants a new and renegotiated meaning (Blomkvist & Holmlid, 2011; Schön, 1983). These meanings, gained through prototyping, influence making of a common, negotiated, and adequate design language.

How to Learn Design Thinking

The question of how learning design thinking and understanding its basic modes of understanding well (see Fig. 3) and how this can be applied in practice, in the context of STEAM education, is an interesting one. We have created our own way of implementing DT in the classroom and now provide some concrete examples of how this learning is supported. The course that uses design thinking in project work does so in the context of the traditional human–computer interaction course that teaches research methods. The course has two prior courses as prerequisites, one offering the introduction to interaction design and the other participatory design approach and making technology for use in everyday life. In addition to teaching research methods through lectures and small group learning sessions, the course aims to address real-world problems by offering semester-long projects in cooperation with external, local organizations. Approximately, 20 real-life based projects are offered per semester. Students work in small design teams of 3–4. Not all projects use design thinking approach, as research questions are very different from project to project. For a portion of projects only, DT is an appropriate approach. Students then get external help to start (a teacher, or an expert from the organization that they work for), from someone who is an expert in DT. This person helps with creating a dialogical space with students, getting them to be familiar with the language and terminology that could be used in the project, and suggests methods and tools that are adequate to start the project. They then wait for students to reflect, engage with the problem, and explore and experiment with suggested methods, language, the literature, and to look for similar situations and solutions found, also in different fields than HCI. For example, one student project group worked for a library that wanted to increase visibility and interest in their science fiction collection. The method suggested to kick off the project was giga mapping, (a method that helps map complex systems), something that students were not familiar with. However, after doing a couple of rounds of mapping, the students started to understand how to think about complexity

Fig. 4 A group of students reflecting over how to increase the visibility of a collection in the library

of the problem and discovered areas where they could make a contribution; see Fig. 4, (Granberg, Traran, & Steinsø, 2017).

Another project used a sustainable design service approach, starting from the question: "How may emerging technologies and connected services be used to create innovative and sustainable solutions within the energy and utilities industries?" They chose DT because they understood that the level of uncertainty and complexity that they had to consider was high. They really wanted to focus on innovative ways to integrate services into a simple and a comprehensible one, placing user's needs in the center. This group started by taking the empathic approach, stepping into user's shoes (Hansen, Hess-Bolstad, & Mjøvik, 2017).

Yet another project had to do with a very open question "How could interaction design and digital media be used to stimulate audience participation in collecting content that inspired them in the young age, and creating an exhibit in a culture house based on this material?" Apart from agreeing what audience participation means, this group started working with images related to the concept of inspiration (Tessem, Lunde, & Dåstøl, 2017).

Service design-oriented projects usually start with use of cards that represent touch points and have students envision alternative "customer journeys." While doing this, students would really get a grip on what a customer journey is, what is the touch point, and what is a service. Thus, dialogical space and the project language around services would be created (Okun, Harfallet, Skrebeliene, & Holm, 2013).

To understand how other professionals talk about design thinking, knowledge production through DT, skills, and mind-sets needed, we conducted a workshop with seventeen participants. Among participants were interaction design educators, social media researchers, librarians from academic and public libraries, design consultants, product designers, and design researchers. The main aim was to see if other participants had different perspectives on how to best transfer DT knowledge in project-based courses. Not all were designers or educators, but the combination of participants' backgrounds was relevant, and they were all familiar with design thinking. For example, design consultants were also teaching their clients about design

Table 2 Results of the three exercises performed in a workshop setting with experts in design thinking (from education, consultancies, innovation)

How to learn design/design thinking when not a professional designer?	
Learn from experts	In STEAM situation, this means that students would need to have access to an expert
Learn by doing	
Practice (repeat)	Participate in as many projects as you can, until you feel like a master
Try and fail (do not be afraid of trying)	
Join formal and informal group	Try to find various communities engaged in DT (user experience groups, maker fairs, DIY enthusiasts, fab labs and others)
Tools and Methods	In the beginning, supporting tools are needed. Later, fun to make them
Reflect!	Thinking about principles of DT, theories and other peoples work with it really helps (read and think)
After the third task	
Learn to communicate well	Communication and shared mind-set are part of the dialogical space constitution
Create a shared mind-set	
Empathy	Methods and tools to gain empathy
Experiential Learning in the center	Learn by doing was on the list above, but this had to do with positive experiences as being central for motivation, also in the learning environment

thinking. Thus, they were all familiar with DT and used it previously in their work. The workshop included the following three short exercises.

The first exercise was entitled "How to learn design/designerly thinking when not a professional designer?" Everyone worked on the problem individually and noted three ways they think best serve the purpose. The second part of the workshop was to create a dialogical space around importance of various answers and ranking them by perceived value. Participants kept ranking and reranking all the views presented. The final table, in decreasing number of votes, is presented in Table 2. The third exercise was to reflect on the first two exercises and see whether something important was forgotten. Again, individually people reflected and added topics that were missing to discussion tables (there were four tables). Reframing the question, the participant found out several topics they felt were missing from previous tasks. Out of nineteen new topics to discuss, six were related to communication, including "Visual representations that include short text," "Communication—being able to make a real shared understanding," "Develop a shared mind-set" (multiple people), and "My own mental/experience journey."

Furthermore, multiple participants pointed out that empathy was forgotten in the first exercise yet that it is very important. Experiential learning was suggested in this round by multiple participants and considered fundamental. Someone also suggested learning by apprenticeship. This workshop showed us the difficulty, even for experts, to express and articulate in a good way to learn (or teach, as some have taken the exercise to mean) design thinking.

Looking at our own work in relation to Table 2, we can say that we have been following all these guidelines, but never in a procedure like manner—each project is a different experience and solves different questions applying different sets of methods and tools. The only form of learning mentioned in Table 2 that we do not include explicitly is making students join formal and informal groups with DT interests. However, sometimes students find them on their own. While the involvement of a teacher, or another person experienced in DT, is important at the start of the project, once the shared understanding is reached, students become very self-sufficient and learn by themselves. They learn by doing, trying, and failing, then practicing some more, until they succeed, or understand why their success eludes them. More details on how this experiential learning model is implemented can be found in (Culén, 2015).

Discussion

In this chapter, we argued that the design thinking approach has a potential to contribute to STEAM education in several different ways. From the linear, well-defined, organized, and controlled ways of solving problems within disciplines constituting the STEM model, yet with the inability to bring these together into a truly integrated model that works in practice, design thinking opens doors to a more open, messy but creative, process.

This messy process, when working in teams, is supported by dialogical spaces, where one can negotiate, make decisions, and learn from others safely. *Dialogical spaces* as such offer a higher degree of intellectual activity (Meinel, Leifer, & Plattner, 2011) and power to team-based projects, as opposed to an individual thinking alone. We have discussed cognitive biases and how they get reduced using DT (Liedtka, 2015). Dialogical spaces, specifically, help to discuss values, focusing illusions and other biases that can emerge in the classroom situation (and avoid overvaluing or undervaluing people, ideas, elements of the design process). Dialogical spaces are a practical tool to respond to them, in particular when they are understood and can be communicated to students at the start of the project work. Students tend to understand and appreciate the value of dialogue and ability to articulate their positions in the context of DT, if the dialogical space is well mediated. In such case, it is one of the main contributors to the feeling of having had positive experience once the project is over.

The design thinking also offers the way of solving problems more *holistically*. This may be the glue needed to connect and keep the other STEAM disciplines on board. Learning design thinking, where different types of thinking are used and are all seen as important part of the process, makes it possible for students to find what they are good at as individuals, and as they contribute to the process, feel like an indispensable part of the team.

Design thinking allows students to focus both on innovative processes and on complex problems. The model in Fig. 3 shows how the innovation model and DT are integrated into a single model that indicates learning styles needed to apply the model in practice. This model may be a useful guide for teachers when they organize teams to work on STEAM problems. The learning styles may be even more important when solving complex problems rather than innovating. The more kinds of *thinking styles and knowledge* the team has represented, their chances for learning through, and solving, a given problem would increase. Thus, from our experience, *creating teams* and creating dialogical spaces in the context of STEAM complex problem-solving are the most important parts to scaffold. Empathy, while important here too, is perhaps more relevant for innovation processes. Furthermore, creativity and engagement in the context of STEAM need to be catered to and supported, so that students may exploit the abilities they are best suited to.

We have seen evidence through our work that creativity, ownership over ideas and engagement through design thinking have an effect on the willingness of teams to engage also in other ways of solving problems that are outside of their disciplinary boundaries. For example, in order to illustrate the underlying principles of the greenhouse effect and teach museum visitors about it, the project team engaged in making their own engine for generating gas (i.e., solved an engineering problem). Sometimes, a project group needs to implement algorithms in programming languages that must be learned for the purpose. Seeing possibilities and alternatives, trying them out, in particular when supported by the team, pushes learning further than any classroom teaching could. The fact that they work on real-life problems, and that the work helps someone in the world outside of the classroom, also motivates students to work harder. Learning new things from STEAM subjects, when a concrete application is kept in mind, is very powerful.

Finding a common language and shared meanings in a dialogical space also includes discussions about responsible design points of view (Kiran, 2012; Roeser, 2012). Asking and answering "What if" questions, speculating on how proposed solutions affect the context, including trying to predict the impact of any proposed solution in comparison with present solutions (if they exist) brings forward designers responsibility for how the world changes. For example, what if a home robot helper stops working, would it be disposed or repaired? What would be consequences? What if only a part stops working, should it be possible to replace the part, rather than having to get a whole new robot? Although in the present, the future is unknown and uncertain, it is our responsibility to map out possible implications of solutions we make. Design is not neutral. The design thinking approach, thus, has to educate students also how to be responsible designers. Our designs, things, systems, and services that we make influence the world we live in. Thus, learning to see, and estimate risks associated with diverse design alternatives, whether they are environmental, ethical, social or economic, is important. In other words, adding A to STEM, in our view, also adds human-centric perspective and human values in a much more explicit way to STEM education, where humans are too often not central.

Conclusion

The aim of this chapter is to leverage design thinking as a way of integrating STEM subjects into STEAM. While art is powerful, it is a more personal endeavor and engagement in the process of making a piece of art. However, design, and especially design thinking, is about integrating various types of knowledge and thinking stiles with the exact same aim as STEAM: to tackle real-life problems, complex problems, that science cannot solve alone. DT is not the work of an individual; it is based on teamwork and is further supported by dialogical spaces and creative, designerly ways of constructing things and meaning in the process. Furthermore, design thinking helps to reduce some cognitive biases often encountered when working in teams. The development of sensitivities to ask and articulate questions becomes transformational, as it requires critical and creative thinking by the whole team. Design thinking, thus, is very far removed from the classical notions of what design does and represents an approach to solving problems, including those of education, in a creative manner.

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Chapter 7
Using Technology to Scaffold Progressive Teaching

Jeppe Bundsgaard

Abstract A *Practice Scaffolding Interactive Platform* (PracSIP) is a social learning platform which supports students in collaborative project-based learning by simulating a professional practice. It puts the core tools of the simulated practice at the students' disposal, and it organizes collaboration, structures the students' activity, and interactively supports subject learning. It facilitates students' development of complex competencies, and at the same time, it supports the students' development of skills defined in the curriculum. The paper introduces the concept, presents the theoretical foundations, and gives an example of a PracSIP

Introduction

An encouraging consensus has arisen in recent decades among researchers and policy organizations in favor of more progressive teaching practices like inquiry-based science education (Barron & Darling-Hammond, 2010; Rocard et al., 2007) and project-based learning (Krajcik & Shin, 2014; OECD Publishing, 2010), giving way to teaching that incorporates science and arts subjects. At the same time, there has been an increased acknowledgment of challenges that are typically encountered in progressive teaching practices, for example, the challenges of organizing collaboration, of structuring activity sequences, of supporting subject learning, of setting and supervising product requirements and standards, and of teacher overview.

The challenges relate to all students, but especially students who struggle with the academic language, and students from homes unfamiliar with education, will experience challenges of knowing what to do, how to do it, and of understanding the language of the project (Gregersen & Mikkelsen, 2007). For these students, getting help in structuring the work process, organizing collaboration and creating

This chapter is based on and expands (Bundsgaard, 2009).

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a product, and getting introduced to the academic language, is pivotal. Not getting this help results in students giving up, trying to stay under the radar, and loosing self-efficacy (Gregersen & Mikkelsen, 2007). Therefore, it can be seen as human rights to get this kind of support.

In this chapter, I introduce the concept of *Practice Scaffolding Interactive Platform* (PracSIP). PracSIP addresses a number of the aforementioned challenges by organizing collaboration, structuring activities, supporting subject learning, and providing tools for production and sharing of and communication about students' products. To explain the principles, I give two examples of PracSIPs developed as ready-to-use material, and after that, I point to how the principles can be used in more handheld teaching practices using stand-alone applications.

What Is a PracSIP?

In their book *Situated learning,* Jean Lave and Etienne Wenger developed the concept of community of practice. A community of practice is a group of individuals participating in communal activity and continuously creating their shared identity through engaging in and contributing to the practices of their communities and thereby developing a shared repertoire (Lave & Wenger, 1991; Wenger, 1998).

David W. Shaffer argues that different communities develop different epistemic frames, which are:

> [...] different ways of knowing, of deciding what is worth knowing, and of adding to the collective body of knowledge and understanding of community [...] such ways of knowing form a coherent core around which effective practices are organized (Shaffer, 2006, p. 10f.).

Shaffer also argues that well-established professions like doctors, engineers, journalists each have a particular learning practice or *practicum*. And by simulating such a practicum, an *epistemic game* makes it possible for students to learn to *think like* doctors, engineers, journalists. That is, they learn to be a part of a particular community of practice. Shaffer gives a number of examples of epistemic games: *Digital Zoo*, "with which players become biomechanical engineers and design virtual creatures" (Shaffer, 2006), *Byline*, an Internet-based publishing tool, which was designed to simulate elements of a journalism practicum (Hatfield & Shaffer, 2006).

Hatfield and Shaffer (2006) define an epistemic game as consisting of "an *activity structure* (the things players do) and a computer-based *epistemic game engine* (the technology players' use) which together simulate the process by which adults become fluent in a particular professional practice" (Hatfield & Shaffer, 2006). The definition does not imply that the epistemic game engine is the one, which organizes the collaboration of the players or structures the activities. Organizing collaboration and activities might be up to the teachers, or it might be a task for the students themselves to find out how to act in the game's setting. A PracSIP is an epistemic game engine that is intended to *scaffold* the full *practice* and therefore includes tools for organizing collaboration and structuring student activities. A PracSIP makes students able to simulate (parts of) the community of practice of a professional setting, and thereby developing competencies which are important from an educational point of view.

The two examples of PracSIPs I present in this chapter are simulations of (parts of) the community of practice in a newspaper editorial office and in a consulting engineer company. *Redaktionen* (*The Editorial Office*) is a PracSIP developed by the Danish newspaper *Ekstra Bladet*. The PracSIP was built on a concept chapter I wrote and participated in the development as a consultant. It supports many of the activities in a journalist's practice such as collaboration, planning, research, writing, and layout. The students write and layout a newspaper which is then sent to a printing office and printed in 500 copies on real newsprint. *Future City* is a PracSIP developed by *The Danish Society of Engineers, IDA*. I participated in the concept development and as a consultant during the development. In *Future City*, students are working as consulting engineers with the aim of giving advice on how to address some of the serious problems that the fictitious *Future City* has with pollution, unemployment, unsuitable infrastructure, use of fossil fuels, etc. Students analyze the city, study possible solutions, discuss and decide on a suggested proposition which they describe and support with scientific and sociological evidence in a presentation. The PracSIP supports the students in their collaboration in and across small expert groups, structure their research, gives just-in-time access to relevant knowledge and information, and supports the teacher in keeping an overview and giving feedback to the students during their work.

Design Principles of a PracSIP

A PracSIP can be designed to support a number of different practices, e.g., project-based learning, inquiry-based science education, and simulation of professional practices as in the two examples in this chapter. These progressive teaching practices are constructivist pedagogic approaches which allot importance to the student's autonomous interdisciplinary and collaborative work with the subject matter.

There is evidence of predominantly positive outcomes in meta-studies and literature reviews on project-based learning (Bradley-Levine & Mosier, 2014; Hixson, Ravitz, & Whisman, 2012; Mergendoller, Maxwell, & Bellisimo, 2006; Schneider, Krajcik, Marx, & Soloway, 2002) problem-based learning (Dochy, Segers, Van den Bossche, & Gijbels, 2003; Walker & Leary, 2009) inquiry-based education (Furtak, Seidel, Iverson, & Briggs, 2012), teaching of critical thinking (CT), i.e., the ability to engage in purposeful, self-regulatory judgment (Abrami et al., 2008).

But these teaching methods and approaches are not without problems: "[…] projects offer many attractive promises, but they are often difficult to implement" (Barron et al., 1998, p. 306; cf. Bundsgaard, 2005, Sects. 5.3.4.3 and 10.1.4.5; Darling-Hammond & Barron, 2010). The challenges can be summarized as:

(1) The challenge of chaotic social contexts (organizing collaboration),

(2) The challenges of what to do next (structure of activity sequences),
(3) The challenge of promoting subject learning central to curriculum standards (support of subject learning),
(4) The challenges of how to produce, share, and communicate about students' products (support of production and communication),
(5) The challenges of monitoring student work and progress (teacher overview).

Barron et al. propose four principles of design that "can lead to doing with understanding rather than doing for the sake of doing" (Barron et al., 1998, p. 273). These principles are:

1. Learning-appropriate goals,
2. Scaffolds that support both student and teacher learning
3. Frequent opportunities for formative self-assessment and revision, and
4. Social organization that promotes participation and result in a sense of agency (ibid.).

Some of the reasons for the challenges can be explained by taking a closer look into communities of practice. Etienne Wenger states three principles, which characterize a community of practice. The members are bound together into a social entity through *mutual engagement*. Members are engaged in actions whose meaning they negotiate continuously. *Joint negotiated enterprise* is the participants' "negotiated response to their situation [which] thus belongs to them in a very profound sense, in spite of all the forces and influences that are beyond their control" (Wenger, 1998, p. 77). The participants have a *shared repertoire of resources*: Words, ways of doing things, routines, actions, artifacts, styles, etc. (Wenger, 1998, p. 83).

The last principle states that the participants have a shared repertoire of rules, steps in a process, knowledge of hierarchies, etc., which are often tacit and inscribed in the practice. Participants in a community of practice know the organization of practice; that is, they know the rules of *what* shall, must, or can be done by *who*, at *what time*, *where,* and *how* in relation to *whom*.

When newcomers are introduced into the community, they get to know the shared repertoire by interacting with more experienced participants as *legitimate peripheral participants* (Lave & Wenger, 1991). But in a community of practice solely consisting of newcomers or one experienced (the teacher) and a number of newcomers, the repertoire of collaboration rules, communication strategies, process steps, etc., must be introduced in another way preferably when it is needed by the individual newcomers, and in a way that makes the process run smoothly. When this fails, the social context is in danger of being chaotic and the newcomers (the students) have problems finding out what to do next.

For that reason, the repertoire has to be more explicit, *reified* when all participants are newcomers, but it still has to be presented in a way that does not overwhelm the students making it difficult for them to figure out when to employ what parts of the repertoire. Thus, in more complex cases students have to be supported in their collaboration as well as in their individual activity. A PracSIP, therefore, is an interactive platform that scaffolds both the students' organization of collaboration and helps to structure their activity.

When participating in a practice, e.g., as a journalist or a consulting engineer, or when performing the tasks in project-based learning or inquiry-based education, students will get experience with the systematic approaches of the practices, that is, the ways to ask questions and the approach and methods used to address issues and solve tasks (Bundsgaard and Fougt, Forthcoming). And the students will experience the need to and benefits from using an academic language or technical terminology, making it possible for them to talk about the world and the tasks in a more precise way, they acquire knowledge about what is and what was in the world seen from the perspective of the given profession or practice, they experience the procedures used to solve tasks, and they practice using the things, tools, and technologies in working with the tasks.

But these systematic approaches, languages, terminologies, knowledge, and tools are not known to the students, or maybe even to the teacher, and therefore the most important part of a PracSIP, and the aspect that ultimately makes it relevant for the school, is that it gives students access to the repertoire of concepts, vocabulary, tools, procedures, etc., of the profession or working method.

But not all parts of the systematic approaches and languages of a professional practice are necessarily central to the school curriculum. Shaffer argues that:

> Developing those epistemic frames provides students with an opportunity to see the world in a variety of ways that are fundamentally grounded in meaningful activity and well aligned with the core skills, habits, and understandings of a postindustrial society (Shaffer, 2005).

But some parts of an epistemic frame might be more relevant in an educational context than others, and some parts are accessible to the students at the given stage in their education. Students in 8th grade might not need or be ready to know how to perform calculations of the power production of a windmill or the exact reduction in NO*x* when changing the infrastructure in a city. And in that sense, they do not perform the total work of a consulting engineer.

On the other hand, some epistemic frames might make it possible to develop more generally relevant competencies. As explained below, a journalism PracSIP, for instance, can support students in developing their competence in writing which can be used in many other contexts.

The design objectives therefore always have to be double. The developers of a PracSIP that simulates a professional practice need to analyze the structure of a reproductive practice (Shaffer, 2005) that is the epistemic frame, of a profession, but they also have to consider which parts of the profession that demands the most important competencies, and finally, they must consider how to support the pedagogical practice to minimize chaos, support student activity, introduce subject knowledge, support production and communication about products, and support teacher overview. These five objectives are equally important, but not necessarily in line with what a professional himself would consider important when developing a PracSIP. For example, in the concept paper describing the underlying principles and the design of *The Editorial Office,* a function intended to support and organize commenting on the first draft of the article was included. The reason for this function was double. First, it was a way of assuring better and more thoroughly revised texts in the final paper. And second, it was a way of focusing on writing to improve the students writing competence and their reflections on their own and other peoples' writing. In the phase of transforming the descriptions in the concept paper to a more thorough description that could form the basis for contractual agreement and system development, the system developers and the people from *Ekstra Bladet* decided to cut away the commentary function. This decision makes sense if one considers that the intention of the platform is to simulate a journalism community of practice. But from an educational point of view, the students' writing competencies are a core educational aim, and the journalist practice makes possible that they practice and reflect on writing in a context, where they recognize the importance of producing a well-structured and well-formulated text that lives up to the genre and stylistic demands of a newspaper article. The commentary function was reintroduced later in the development process.

To sum up the core design principles of a PracSIP:

A PracSIP facilitates simulation of dimensions of an authentic community of practice or supports a complex progressive teaching method, and scaffolds the practice by

- organizing collaboration,
- structuring activities,
- introducing approaches, languages, and terminologies,
- providing tools for production and sharing of students' products,

and gives the teacher an overview of what is going on, and how students progress and support his/her communication with students about their products and processes.

Scaffolding

The term scaffolding was introduced by Wood, Bruner, and Ross in 1976.

> This scaffolding consists essentially of the adult "controlling" those elements of the task that are initially beyond the learner's capacity, thus permitting him to concentrate upon and complete only those elements that are within his/her range of competence. The task thus proceeds to a successful conclusion (Wood, Bruner, & Ross, 1976, p. 90).

In this initial conception, the concept was used to describe cooperation on well-defined simple tasks, where a parent or a teacher helps a student. The term has been used in a wide area of other contexts, and I will continue the extension of the use by talking about scaffolding of collaboration, and scaffolding of individual and collective activity sequences. *The PracSIP thus scaffolds practice*. I will argue below that it meets the demands of the three components of the scaffolding framework that Roy Pea points out (Pea, 2004, p. 431f.): (1) *Fading*: It must become possible for the learner to do without the scaffold through the use of the scaffold. (2) *Channeling* and *focusing*: The scaffold can consist of reduction of the degrees of freedom for the learner to direct him to the task. And (3) *modeling*: The scaffold can be carried out by modeling more advanced solutions to the task.

Organizing Collaboration

In a community of practice, mutual engagement among other things finds expression through hierarchies, collaboration, and agreements on how to get the job done, how to divide the responsibility, etc.

In a simulated community of practice, which consists of newcomers, these organizational challenges might be too overwhelming (cf. Bundsgaard, 2005, Sect. 5.3.4.3). A PracSIP includes tools to organize the collaboration, e.g., by organizing the distribution of roles and responsibilities or by organizing time, deadlines, communication channels, etc.

In *The Editorial Office,* it is done by supporting the distribution of students in different editorial offices, and by a time planning and task distribution tool (producing a simple Gantt chart). The planner (see Fig. 7.1) helps the students decide on which articles to write, who has the responsibility of each subtask (researching, taking photographs, writing, layout, etc.), and when each subtask has its deadline. The students are supposed to continuously indicate on the status bar which article and subtask they are working on or have finished.

Thereby, the students have the possibility of being aware of what their current assignment is, and when they are supposed to be finished. And their teacher has access to an overview of the students' progress.

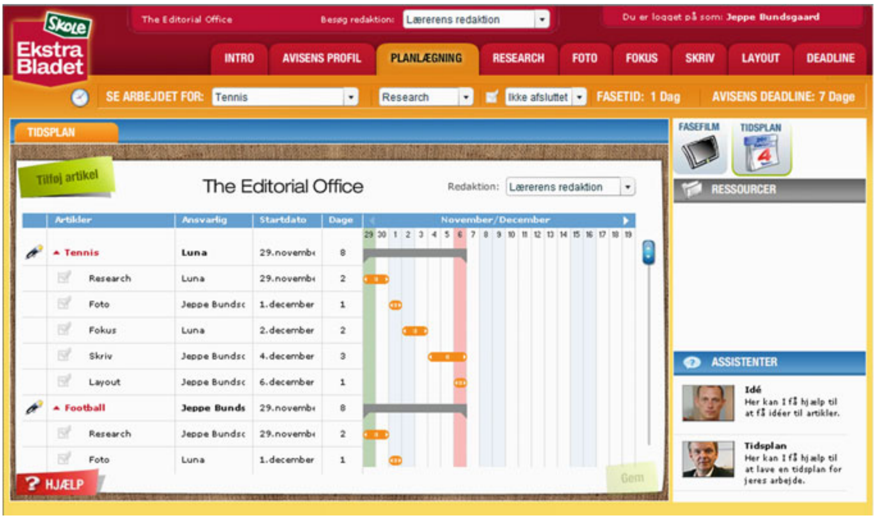

Fig. 7.1 Planner in *The Editorial Office*

In *Future City,* students in the class are organized in expert groups each having responsibility for doing inquiries into and coming up with suggestions about a specific aspect of the city (e.g., energy use, infrastructure, or production). The groups are given different knowledge about the city, which they can use when they meet in cross-disciplinary groups to discuss what to focus on in the common presentation with suggestions for the city. The organization of these meetings is also supported by the system.

The system supports the organization by keeping track of who is in which group, and by helping the teacher assigning tasks that are relevant for the different groups. The system tells the students what the task of today is, and where to get more information. The teacher can get an overview of what he/she needs to prepare for the different groups in each lesson (see Fig. 7.2).

Structuring Activity Sequences

The *shared repertoire of resources* is a cornerstone of the community of practice. An important resource is knowledge of sequences in which activities are supposed to be carried out or dependencies in between activities. For example, you do not lay out an article before it is finished and revised.

In *The Editorial Office,* a number of activity sequences are *channeled*, that is scaffolded by reducing the degrees of freedom. The overall sequence of planning,

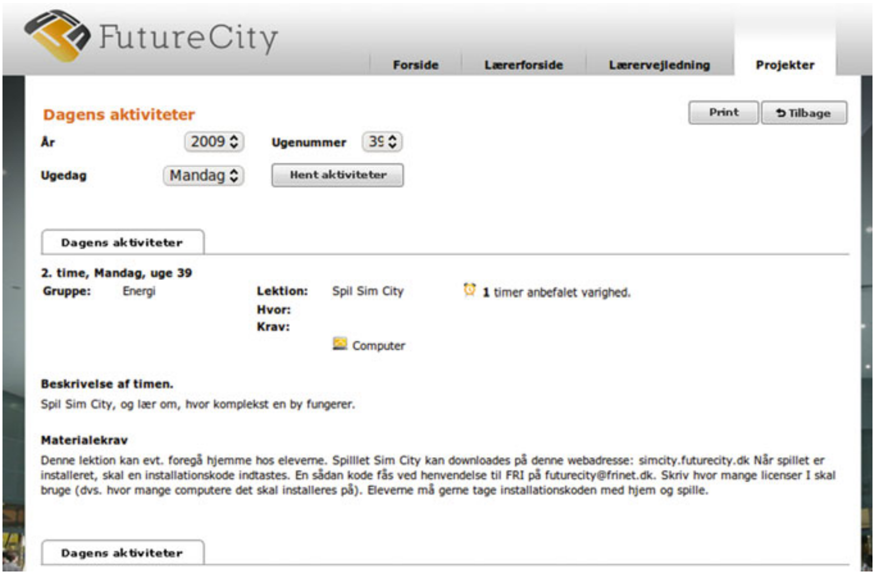

Fig. 7.2 Today's activities shown to the teacher in *Future City*

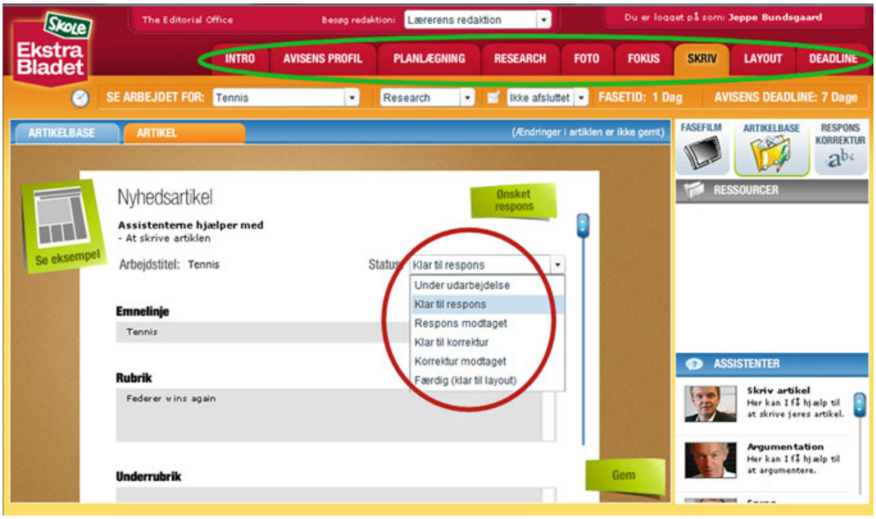

Fig. 7.3 Structuring the students' work process through phases (the green ellipsis) and states in the production of an article (the red ellipsis)

researching, focusing, writing, and layout is reproduced in the order of the menu points (cf. the green ellipse in Fig. 7.3).

The process of writing and revising an article is also structured by the PracSIP (cf. the red ellipse in Fig. 7.3). When the student thinks his/her article is finished, he/she saves it and is then asked to change the status of the article by choosing from a list of possible values, the first after "being prepared" being "ready for comments" and the last one being "ready for layout." The article does not occur in the layout tool before it has been assigned the status "ready for layout." The PracSIP thereby impose a certain sequence of activities, but to avoid making the system to inflexible, it is possible to skip some of the steps in the sequence. This can be seen as a way of *fading* the PracSIP out when the students have learned to organize their sequence of activities themselves.

In Future City, the concept of a weekly schedule has been chosen to help students and teachers keep track of the process (see Fig. 7.4). The activities are split into phases, for example, an inspiration phase, an education phase ("become an engineer"), an innovation phase, and a negotiation phase. Each phase has a number of pre-described lessons. The teacher is presented with a pool of mandatory and optional lessons to distribute over the time slots available for the project. When the students open the weekly schedule, they can see what's next, and click on the active lesson to get the task description and the material they need to use. If the students get behind schedule, they can keep track of how much they need to speed up in order to get on time again, and the teacher can follow up as well.

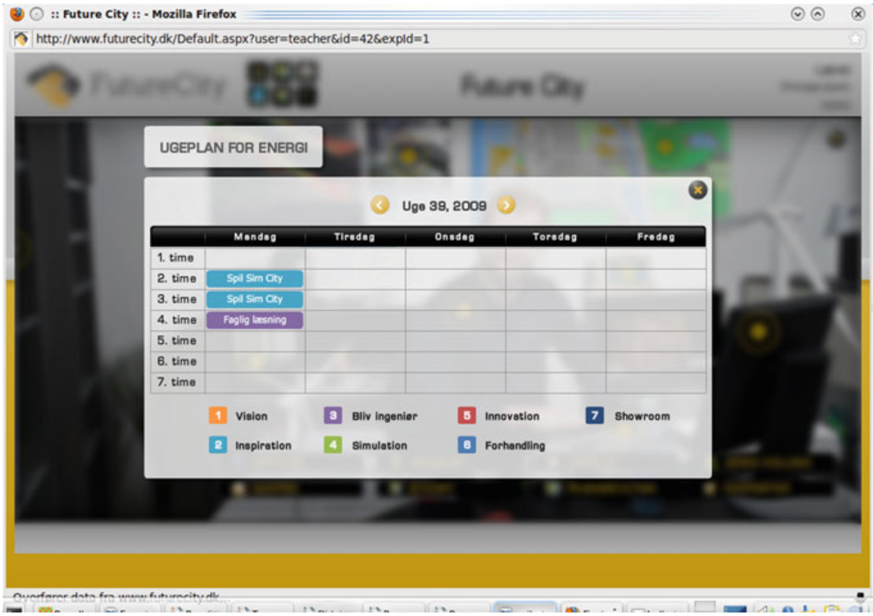

Fig. 7.4 Weekly schedule in *Future City*

Subject Learning

Simulating a community of practice is a way to improve motivation and to support students' development of multiple epistemic frames. But this might be viewed as secondary to the development of transferable more or less basic skills and knowledge. Often the resources developed in a community of practice build on knowledge and skills, which can be seen as very relevant from a curriculum point of view. A PracSIP therefore also supports the students' development of skills and knowledge that is relevant to them.

This can be done through integration of *interactive assistants*, a concept of computer-assisted learning which I have introduced in (Bundsgaard, 2005, Sect. 5.3.3). An interactive assistant is a computer program, which guides the students through a complex problem, and helps the student build up knowledge and methods relevant to the problem and the curriculum. An interactive assistant builds on a description of an academic area, method or problem, or a core task in the community of practice; it integrates the student's project, sets the scene for the student to do the thinking, uses the input from the student during the process, and collects it in an overview in the end that the student may print and discuss with the teacher and other students. Interactive assistants can be developed for individual use, and for use in groups. In the latter case, students can be asked to discuss and contribute with different perspectives and ideas.

In *Future City,* there are a number of interactive assistants for each of the phases in the process. Figure 7.5 shows a screen from an interactive assistant helping the students inquire into the pros and cons of using district heating. Before working with the assistant, the students have read about district heating (and other heating methods), and they have completed simple experiments with different kinds of heating.

The assistant starts by asking the students to explain how district heating works. This information is then used in the screen shown in Fig. 7.5 to remind students of their answer, when they are thinking about two good reasons for using district heating. To the right, at the whiteboard, students are presented with information they can use when discussing the questions.

At later steps, students are asked to think of disadvantages of district heating and to compare to other heating methods.

Other interactive assistants in *Future City* support students in other aspects of the area of energy use and production, and in other expert areas, but also in coming up with ideas, discussing suggestions from the different expert groups, preparing a presentation and so on.

In *The Editorial Office,* there are more than 40 such interactive assistants, helping the students in all aspects of the journalist practice, ranging from coming up with ideas for articles, preparing interviews, focusing in on an angle, writing in different genres, giving feedback to other students, laying out the paper, evaluating the process, and so on.

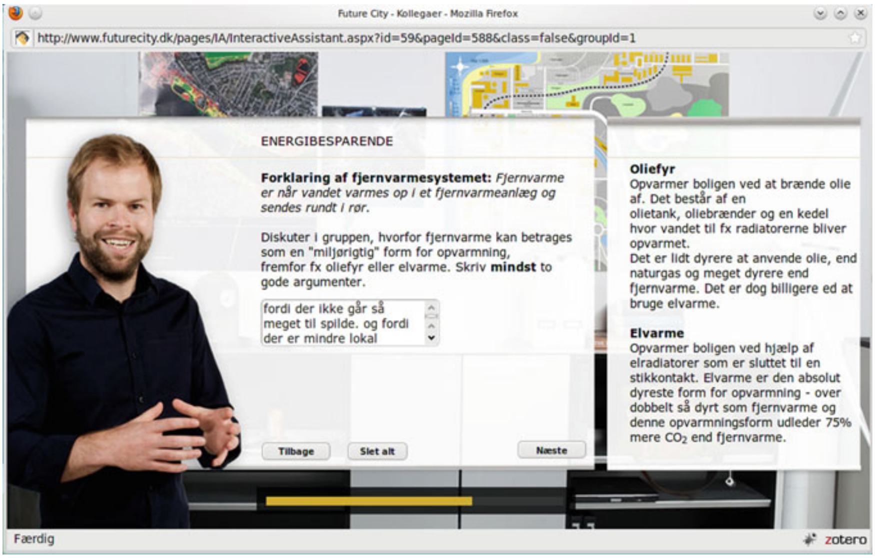

Fig. 7.5 Interactive assistant helping inquire into the pros and cons of using district heating

Production, Sharing, and Communication About Products

A pivotal part of the progressive teaching methods is students' production of products, both as interim products, outlines, drafts, and so on. Core parts of the learning process are evolving, visible, and adjustable in and through these products if the teacher can get access to them.

These processes are supported in different ways in *The Editorial Office* and *Future City*.

In *The Editorial Office,* students can use predefined templates for writing different types of journalistic texts, they can upload, share, and edit photographs, the reports from their interactive assistants are saved and visible for their peers and the teacher, etc. Communication about the products is supported in a number of ways. For example, students are helped to organize, comment, and proofread each others' articles. When a student thinks he/she has finished his/her article, he/she changes the status of the article to "ready for comments" (cf. Fig. 7.3), and then he/she is asked to use an interactive assistant which helps him/her indicate what kind of comments he/she thinks he/she needs; now, the article appears in the list of articles ready for comments. The students' teacher and classmates are now able to comment on the article by using an interactive assistant made for the purpose. Giving and receiving comments are very central to the development of writing competence. When the student has revised his/her article, he/she marks it ready for proofreading, and when some of his/her classmates or his/her teacher has proofread it, he/she finally can mark it ready for layout.

In the layout tool, students can drag in the articles and photographs they have produced during the process, and combine them into a professionally looking newspaper.

Future City supports students in producing a slide show presentation (see Fig. 7.6). During the expert group phases, students use the presentation tool to design a presentation that promotes the solutions they have decided on. When the class has agreed on which aspects of the solutions it will focus on, the expert groups go back to their presentations and edit them so they can fit into the common presentation.

Teacher's Overview

One of the challenges in teaching practices where students are working individually or collaboratively on projects and products is for the teacher to have an overview of what students are doing, what they learn, and what they produce. This challenge has already been addressed a number of times above. Further, in *Future City* teachers have access to a list of the students' interactive assistant reports (see Fig. 7.7), which gives them easy access to a core part of the students' learning process, and a way to give feedback to their work.

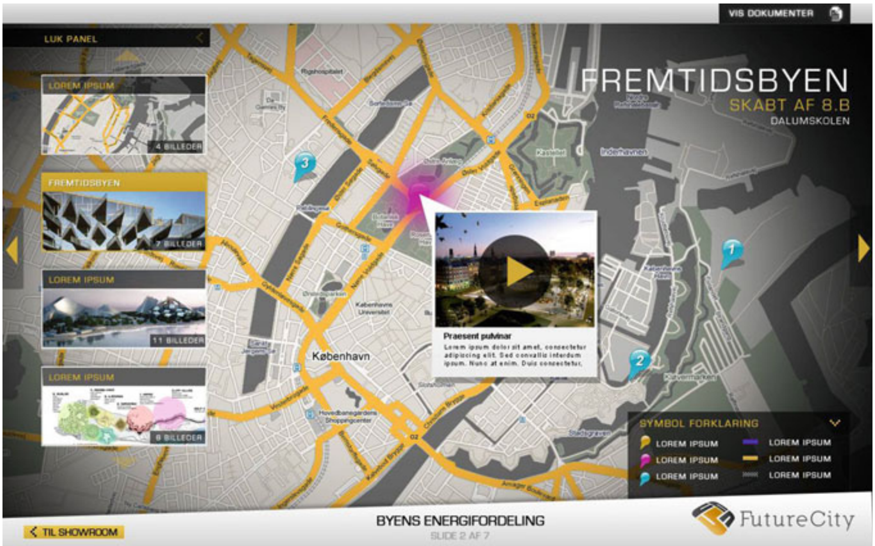

Fig. 7.6 Tool to support students producing a slide show presentation

Fig. 7.7 Teacher's overview of students' reports from the interactive assistants in *Future City*

In *The Editorial Office,* the teacher can log in as a member of the different editorial teams to see the progress, task statuses, interactive reports, etc.

Hand-Holding the PracSIP Principles

In explaining the PracSIP principles, I have shown how computers can be used to support more advanced, progressive teaching practices, and address a number of the issues that have been pointed out in research and experience. But still, there are only very few systems fully implementing the PracSIP principles. Therefore in many cases, teachers and students will have to use a patchwork of technologies to support the complex practices. In the following, I will give a few examples on how to use standard or free and open-source software in progressive teaching practices.

When the teacher prepares a unit, he/she can use flowcharting software like Diagramo.com or the functionality available in most word processing programs to structure the unit in phases and sub-phases, to indicate what is intended to be done in class, individually or in groups, how products from one phase float into a later phase, etc. Such a flowchart can later be used to communicate the overall structure to the students and to help keep track of where the students are in the process.

Another way to structure the work is by producing a Web site for example in Wordpress with a sub-page for each phase in the process. Each page can consist of a description of what is going to happen, what the tasks and assignments are, and what the products to be produced in this phase are. Material can be made available, and in even more advanced situations, the students can be asked to upload their products for the teacher to see and comment.

There are many ways to support the organization. One way is to produce Gantt charts for example by using GanttProject.biz. In Gantt charts, the phases can be detailed into sub-phases, dependencies and deadlines can be set, and responsibility can be assigned to groups or individual students. A more simple way to support organization is to use a spreadsheet application with each row for example representing a task, deadline, responsibility, status, and comments.

The functions of an interactive assistant to support students' development of academic language, terminologies, knowledge, tools, and so on can be simulated using a questionnaire technology, for example, LimeSurvey, where students are led through the reflections of a given topic and where their answers are collected and presented to them in the end. Or it can be done even more simply by giving them explanations and asking them questions in a document.

Today sharing of products is easy and widespread using one of the many cloud-solutions like OneDrive, Google Drive, Dropbox, or open-source alternatives like Owncloud. And it has become more and more common to use these technologies to co-produce documents, presentations, and so on. These technologies can also be used for feedback and communication about the students' products. Of course, these suggestions in no way exhaust the possibilities for support of progressive teaching practices, but they show that it is technically feasible and rather straightforward.

Conclusion

A Practice Scaffolding Interactive Platform (a *PracSIP*) is an artifact, a tool informed by practice, a transformation of resources from tacit structures to explicit structures. It is not a simulator as is a flight simulator because it does not graphically simulate a world or a person's point of view. It is a tool used by people in *their* simulation of a practice. The PracSIP organizes and structures the participant's practice and thereby scaffolds their learning.

This chapter has shown that computers can be used in various ways to support more complex teaching practices. *The Editorial Office* was not developed specifically for STEM teaching, but it has been used in many cases to give students experience in communicating knowledge from the STEM area.

Future City is a case in point showing that when working in the STEM area, a lot of "soft" competencies are needed, like writing texts, presentation of results, collaboration, and organizing collaboration, communication, etc. PracSIPs are intended to support these practices, so students can improve on their competencies both in the STEM and the arts field in authentic contexts.

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Chapter 8
Expressive Robotics

Viet Vu, David Liu and Kreshnik Begolli

Abstract The purpose of this chapter is to describe a new STEAM curriculum that integrates expressive movement into a robotics curriculum. Based on previous research of art and STEM learning, a new two-week summer camp curriculum was developed by the Beall Center for Art and Technology. In this two-week summer program, junior high and high school students learn and apply movements drawn from art, theater, and dance to their learning about computer programming and robotic design. Through student comments and project designs, we see that this new robotics curriculum has unique opportunities to engage students in an integrated arts-based STEM curriculum. New innovations in STEAM education have opened doors for students to engage in science where creativity is relevant and humanistic.

Global economic forces have compelled schools to design curricula that prepare their students for careers in science, technology, engineering, and math (STEM) (Bonvillian, 2002; PCAST, 2012; The White House, 2009). One of the ways in which schools have responded is by developing robotics curricula, which teach students how to build and program the robots' behaviors. Robotics has gained traction as a means of preparing students for careers in STEM, as these activities usually require students to use their knowledge and skills from multiple disciplines (Papert, 1980; Rogers & Portsmore, 2004). Additionally, studies have demonstrated that a curriculum emphasizing robotics can raise test scores and increase interest in STEM-related careers and activities (Barker & Ansorge, 2007). There has been a push for researchers and educators to design and advocate for more dynamic methods that improve and reframe STEM education. This shift has included integrating robotics engineering with complementary disciplines, such as art. Within the STEM workforce, there

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has been a hiring trend that favors employees whose skillsets are much more art- and creativity-related rather than science- and math-related (Lichtenberg, Woock, & Wright, 2008). Companies want workers who can brainstorm, problem solve, collaborate creatively, and contribute/communicate innovative ideas—commonly called higher-order thinking (HOT) skills (Partnership for 21st Century Learning, 2017). Helping children develop these skills has become a primary goal for educational policy (Obama, Strategy for American Innovation, 2011). Consequently, there has been increasing interest in integrating arts-based instruction into STEM curricula, a new approach known as STEAM (Maeda, 2012).

The evidence suggests that engagement in an art form may positively impact HOT skills. For example, prior research finds that connecting writing with drawing resulted in responses that were better organized and more detailed (Andrzejczak, Trainin, & Poldberg, 2005) and participating in creative drama-based activities resulted in increases in attitudes and conceptual knowledge of science concepts (Hendrix, Eick, & Shannon, 2012). This has led to a pedagogical shift toward integrating arts and creativity into STEM. By integrating artistic thinking, such as movement and emotions, scientists and engineers are able to create relevant products and services for people and in turn make STEM more humanistic (Fisher & Mahajan, 2003, 2010; Wulf, 2004). Advocates of STEAM have also stated that the technical and social aspects of engaging in STEM go hand in hand (Hynes & Swenson, 2013). Engaging in STEAM results in a paradigm shift that disrupts the structured flow of thinking of traditional STEM instruction with affordances such as aesthetics, design, and imagination (Watson & Watson, 2013). Blurring the line between STEM and art exposes students to the world of imagination by reconfiguring the very narrow ways that people traditionally think of as “doing science.”

From a psychological perspective, a plausible explanation for the positive effects of art-integrated STEM learning is that students gain more confidence and self-awareness through personal expression. More importantly, it improves attention, which generally improves the cognitive elements of learning (The Dana Foundation, 2009). Additionally, the last two decades have seen an emergence of studies that utilize psychological evidence from the science of learning to foster children’s capacity for HOT skills (Booth et al., 2017; Koedinger, Booth, & Klahr, 2013; Mayer, 2012; Pashler et al., 2007; Richland & Begolli, 2016; Richland & Simms, 2015; Roediger & Pyc, 2012). These approaches, coupled with art integration, could greatly benefit the creation of humanistic products and services by fostering our future generations’ HOT skills in a STEM context.

Based on these various strategies across multiple domains, the Beall Center for Art and Technology developed a new two-week summer camp curriculum. In this summer program, students learn and apply movements drawn from art, theater, and dance to robotics design and programming. This culminates in a final project that requires students to integrate their knowledge of human movement with their understanding of computer programming to control robotic behavior. In the following sections, we present the theoretical framework, describe the curriculum, and present two case studies to illustrate the curriculum.

Theoretical Framework

To develop a robotics curriculum that fosters HOT skills, we drew from the theory of embodied cognition and analogical reasoning. We chose embodied cognition for two reasons. First, embodied cognition has guided robotic design in industrial applications and in academic research (Pfeifer & Bongard, 2007) making it relevant for students' engagement in robotics. Second, it allows for the seamless integration of art, specifically expressive movements, as a vehicle to teach complex ideas to young students learning robotics (Kirsch, 2013).

Embodied cognition challenges the notion that learning is only in the mind; rather, embodied cognition postulates that learning is within our bodies and occurs through our actions and interactions with objects and the physical world (Kirsch, 2013; Varela, Thomson, & Rosch, 1991). Through the lens of embodied cognition, physical activity "can help drive thought…and improves or reshapes inner processes" (Kirsch, 2013, p. 325). In fact, Kirsch (2013) found that learning and cognition through observations and mental practice were inferior compared to learning through movement and action. A well-known study of elementary school students in India illustrates the impact of embodied cognition. In this study, students were taught to solve multiplication problems using an abacus. When the abacus was removed, students still flicked their fingers as though moving the beads of an imaginary abacus. To test whether this movement of the fingers contributed to student performance, researchers prohibited students from making imaginary gestures. Without the ability to make these gestures, students performed poorly (Frank & Barner, 2012; Hatano, Miyake, & Binks, 1977). This work has made great strides in explicating the role of contextualized physical movement and sensory input in the development of learners' abstract, decontextualized knowledge of mathematics and science (see Weisberg & Newcombe, 2017 for a review).

Analogical reasoning is thought to underpin our ability to draw connections between our contextualized, physical knowledge, and the abstract knowledge necessary for HOT (Cooperrider, Gentner, & Goldin-Meadow, 2016). While Bloom's taxonomy has received the majority of attention for its explication of HOT, work on analogical reasoning has shown the mechanisms that underpin HOT (Richland & Simms, 2015). Analogical reasoning is our ability to apply our knowledge from a known context to solve problems in novel contexts (Gentner, 1983; Gick & Holyoak, 1983; Schwartz, Bransford, & Sears, 2005). These processes bolster our ability to learn via comparing and contrasting, a skill that has been deemed critical for STEM learning (Common Core State Standards, 2010; National Mathematics Advisory Panel, 2008; Next Generation Science Standards, 2013).

The most critical research findings and implications for developing our curriculum have been that students regularly fail to transfer their knowledge without adequate instructional supports (Begolli et al., 2018). Students learn better when they are given a schema that underlies multiple examples (Gick & Holyoak, 1983) and examples that visually align (Star & Rittle-Johnson, 2009; for a review, see Richland, Begolli, Simms, Frausel, & Lyons, 2017). Another key scaffold for developing creative solutions to problems is to prompt students to self-explore before engaging in comparisons (Schwartz, Chase, & Chin, 2011; Schwartz & Martin, 2004). We employ these principles of analogical reasoning to scaffold students' connection-making between three parts of our robotics curriculum: *expressive movement*, *lecture/coding*, and *robot creation*.

We use principles of embodied cognition and analogical reasoning to develop a new STEAM curriculum that integrates expressive movement into a robotics curriculum. We describe the context, curriculum, and outcomes of its implementation in the following sections.

A Tale of Two Robots: Context and Participants

In this section, we briefly describe the participants (both program leaders and students), the context in which the curriculum is executed, and the material resources used to deliver the curriculum.

Participants

The summer camp curriculum was designed for students in middle to high school who did not have any prior coding experience. Program leaders were undergraduate students who had some coding experience, with skill levels ranging from intermediate to advanced. Many of the program leaders also had some background in fine arts. Other program staff included the director of the program who had a background and the program manager who both had a fine arts background. Various guests from the technology industry, such as IBM and Disney, were invited to speak with the students.

Context

Expressive Robotics is a summer program that takes place over the course of two weeks and is sponsored by a California university's School of the Arts, as an outreach program. The first week of the curriculum focuses on expressive movement activities. Movement activities are guided by the program leaders. Following the movement activities, the program leaders guide the students through structured learning activities that revolve around coding. Then, students follow a Project Handout, in which they practice coding and building small projects. In each coding activity, the Project Handout includes a diagram of the final outcome, required parts, and the codes needed. The second week of the curriculum has a more flexible structure; students are able to freely code, use materials, receive feedback, and create their robot.

Throughout the program, students also receive guest lectures from representatives from the technology and art industry. The culmination of this program is the creation of a robot that expresses emotions through its actions. On the last day of the program, students' peers and families are invited to an art gallery show that showcases their robots.

Material Resources

The material resources in this program include a makerspace and computer laboratory for students to code. In the computer laboratory, tables are set up so that students face the front of the projector. Each table has two chairs and one computer, so that students work in pairs. Students use Arduino Programming to code their robots. Students are given Project Handouts which include short practice activities to code and build robots. A material list and example codes are also provided to participants. Adjacent to the computer laboratory is two 3-D printers, the use of which occurs at the discretion of the program leaders. On the opposite end of the computer laboratory is a makerspace which has all the materials needed to construct robots (e.g., sensors, resistors, breadboards, and diodes) as well as art materials (e.g., colored paper, feathers, pipe cleaners, and glue). Students' access to the makerspace is limited during the first week and expanded during the second week. To foster their metacognitive skills, students are provided with student journals where they could reflect on their learning.

Curriculum

In this two-week curriculum, junior high and high school students are introduced to coding and robotics through movement exercises that connect movement to coding and robotics vocabulary and concepts. The curriculum achieves these learning objectives through five different modules. This section describes the guiding questions of the movement exercise, the learning outcomes of each movement activity, and the coding concept or activity that connects to the movement exercise.

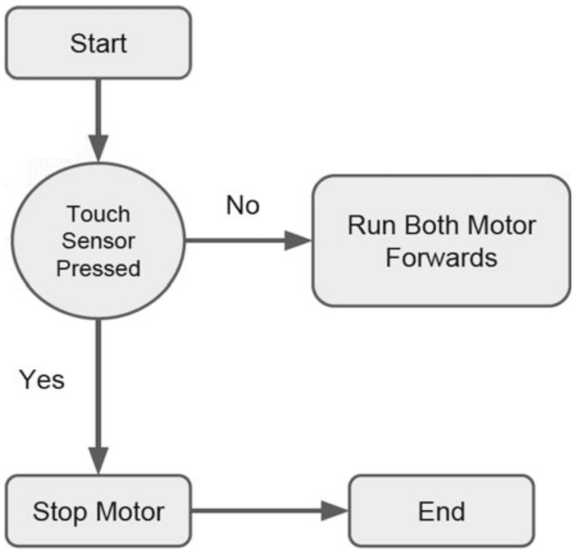
Movement Exercise 1: Breaking the Ice

In the first module, students learn that movement is an integral component of programming robots; this is done using an icebreaker activity that combines social interactions and movement vocabulary (e.g., *if*, *then*, *else*, and *repeat*), and movement concepts (e.g., moving, touching, and looking). For example, with age-appropriate music playing in the background, students are asked to walk around the room while avoiding eye contact with other classmates. *If* the music stops, *then* they stop and shake hands with the nearest person, state their name, and say something that is on their mind—this could be one word, an entire sentence, a whisper or a scream—or *else* they continue walking. They *repeat* this process until they have introduced themselves to all of the students in the room. After the activity, students are asked to consider the connections between programming and the movements they made. This discussion is guided by questions, including the following: How did shaking hands with other people change how you feel toward them? How do the activities relate to programming computers and robotics?

Explicit connections between movement exercises and coding are made through a series of lectures and activities in which students create visual movement-programming flowcharts.

The coding activity that accompanies the first movement exercise is visual: the creation of a flowchart. During this activity, students map out the behaviors, orders, actions, and statements of their robots. Behaviors are defined as "anything a robot does, such as moving, turning on a motor, blinking an LED, or playing tunes." The instructors explain that complex behaviors can be broken down into simpler and smaller parts, like the icebreaker. Students are then asked to create a map using arrows, which represent the flow of logic, and shapes, which represent the behavior (see Image 8.1). The coding activity is connected to the movement exercise in that students have to think about how their movement is broken down into small behaviors, similar to how a robot's movements are broken down into smaller codes.

Image 8.1 Visual image of robotic behavior



Movement Exercise 2: Expressive Action and Reaction

Students are introduced to the embodied sensations of directions (e.g., "stop," "faster") in relationship to their individual physicality and group experiences. For this module, students complete two activities. In the first activity, students are asked to move as a group. Everyone walks around the room in the same direction and at the same speed. The goal for students is to keep together as a group and match other students' changes in speed. *If* anyone calls out "stop," *then* the group has to freeze in position. *If* anyone calls out "faster" or "slower," *then* the group has to adjust speed accordingly. For the second activity, students work in pairs. They face each other, standing two to three feet apart, and choose one person to start. The first person chooses an emotion to express and shares it with his or her partners using only arm and leg movements. The second person responds to the emotion in the same way. Students complete several cycles, with changing speed and intensity.

After the activities, students are asked questions to guide their thinking about the relevance of these activities and to prepare them for the lectures that connect the movements and coding. These questions include the following: Is there anything you can do to make these basic behaviors of stop/go faster/slower more expressive? How? What is the relationship between action/reaction or cause/effect? Is it predictable?

After the discussion questions, students are introduced to the concept of *If-Else* statements and how they guide the decision-making processes of robots. Students are first shown the definition, followed by the syntax, a flowchart illustrating actions based on if-then-else conditions, and finally specific examples of *If-Else* statements. As part of this activity, students are guided to compare and draw connections between humans' visual and audio sensory input and a robot's sensory inputs.

The coding activity that accompanies the second movement exercise is creating a push-button serial monitor and various circuits that buzz and play melodies. Students are also handed a document that describes different Boolean logic and loop statements such as "==" which represents "equal to." For example, *if* a button is pressed (i.e., buttonState==HIGH), *then* it will create a tone or *else* there will be no tone. The coding activity is connected to the movement exercise in that students have to incorporate *If-Else* conditions in their codes.

Movement Exercise 3: Imagination, Intensity, Stillness, and Noise

Students express speed and intensity through movement. They learn to use silence and timing as to compose a series of movements, with a focus on silence as its own experience and as a tool to accentuate movements, build suspense, and direct a viewer's attention. As applied to a robot, students learn that segmented times of movement, and non-movement, mixed with timing can control a viewer's experience.

These exercises are derived from Chekhov's introductory exercises and have been altered to highlight mental projection onto the individual body. The purpose is to create freedom of movement within the body in relation to psychological processes. Imagination is utilized to help students visualize movement in certain areas of the body.

This module consists of three activities: Activity 1 teaches students about change in speed; Activity 2 teaches students about contraction and expansion; Activity 3 teaches students how stillness can be used to surprise an audience.

In Activity 1, students stand with their eyes closed, imagining that one part of their body is moving in an uninterrupted way. Following this, students move in the way they imagined. First, they move only part of their body, and then they add another part. They are instructed to perform their movements slowly at first, then faster.

In Activity 2, students imagine moving their bodies with the smallest motion possible and then the largest motion possible. Next, students move in the small motions they have imagined, such as scrunching down, and the largest, such as waving arms and taking large steps. Students are also introduced to other contractions and expansions such as slow/fast, fast/choppy, and heavy/light.

In Activity 3, students are asked to stay as still as possible and think about ways to surprise the rest of the group. Students are allowed to wait long periods of time to build tension. Students engage in rounds of building suspense and surprising each other. Discussion questions at the end of the module include the following: How is thinking about intensity of movement important to programming robots? How would you feel watching a robot move in these different ways? How can you program your robot to surprise someone? To build suspense? How can you use this kind of timing and intensity to program your robot?

The coding activity that accompanies the third movement exercise involves programming LED lights to change in speed, as well as contract and expand. For example, LED lights can be arranged in a row and blink slower the higher the number of LED lights (similar to Activity 1), programmed to either blink at maximum or minimum brightness (similar to Activity 2), be, and randomly set so that the number of lights that blink is unpredictable (similar to Activity 3). The coding activity is connected to the movement exercise in that it asks students to explore changing speed, including contraction or expansion, and express or induce emotions through the blinking LEDs.

Movement Exercise 4: Experimenting with Materials

Through movement activities, students have opportunities to experiment with different materials and learn the ways that materials can affect the movements of robots. This learning module is composed of two activities. In Activity 1, students learn to move with materials individually; in Activity 2, students work with the materials in pairs.

For Activity 1, each student chooses different materials, so that they can see how each moves. They are asked to experiment with different materials and movements of varying intensity (e.g., fast, slow). In Activity 2, students form pairs. Together, they experiment with different materials and find different ways to move together while using the material. Discussion questions after the activities include the following: How can you make the materials move? How does the material move you? What materials moved in more interesting ways than others? How can we design a robot to move using these materials in these ways?

The coding activity that accompanies the fourth movement exercise is the construction of a simple structure out of the materials in the makerspace, to build a kinetic project. The project students complete has to utilize a motor and electronics components and must perform a simple behavior. The coding activity connects to the movement exercise by asking students to think about how objects move and how they could code their robots to perform that movement.

Movement Exercise 5: Improvisation and Rule Sets

The movement exercises in this learning module are built on theater activities that help actors lead through improvisation. This is important to the final performance scenario, in which students create a dynamic narrative to accommodate the shifting conditions of various contexts that robots encounter. This exercise builds on the ideas of the previous exercises, including timing and social interactions, and support students as they move toward thinking about how to create a group narrative.

This exercise module is composed of only one activity. In this activity, students are asked to think of how they would actually move when they feel a certain way, and then they are asked to move that way. Possible feelings and emotions include energetic, goofy, silly, dizzy, gloomy, disappointed, confused, cold, anxious, afraid, hot, tired, sleepy, motivated, shy, and obnoxious. Additionally, they are asked to adjust the intensity and/or speed of their movements and to use movement to respond to what a classmate does around them. After the performance component, students choose an emotion and an expressive movement that they want to program into their robot. Discussion questions for this module included the following: Can anyone guess what words other people might have chosen? How can you tell? Do you feel like you were having a kind of conversation through these movements? Was it easier to come up with different interpretations of the words when you focused on your speed, breaks, or intensity of your movement?

There is no specific coding activity that follows this movement exercise. After they complete this movement exercise, students start drafting a model of their proposed robots and their artist statements describing their robots.

Engaging in Arts-Based STEAM Curriculum

After completing the movement exercises, students spend the second week of the camp brainstorming and creating an expressive robot. In this section, we describe two case studies from the implementation of this curriculum: The Artortoise and the Babushka. For their projects, students are asked to incorporate the following components: at least two sensors, at least two motors, and one or more Expressive material. Students are also asked to create a sketch of their robot and receive feedback from the artistic director of the program and the program manager. Students craft a description for their project, engage in an art critique with peers, and present their final projects in an art gallery for friends and family. Throughout the entire program, students have access to undergraduate student mentors and staff members who have experiences in art, engineering, and technology.

The Artortoise: A Drawing Robotic Tortoise

Description. This robot was constructed with a wheel on the bottom and a frame on top that contained all the wires and breadboards in order (see Image 8.2). All of the wires were covered with the tortoiseshell made from paper and felt. At the tail of the tortoise were three buttons, labeled 1, 2, and 3. The emotion displayed by the robot included the blinking of its eyes to demonstrate joy after an art piece was completed. Below is an excerpt of the description of the Artortoise from the student journals.

We will have a robot that can drive and draw a picture. On the back of the robot, there are three buttons. Depending on what button you press, the robot's eyes will light up a specific color and will draw a pre-programmed picture. The robot will draw a picture by driving itself. A marker will be attached at the front, so by the movement of the robot driving, the marker will move and form a picture. Each of the three pictures should express a different emotion.

Coding Connections. The Artortoise had one code that drove most of the movements of robot. *If* the first button was pushed, *then* the robot would start drawing the first picture. However, *if* the first button was not pushed, the *else* code would check if the second button was pushed. *If* the second button was not pushed, *then* the else code checked whether the third and final button was pushed.

Direct connections of their coding can be made to various movement activities. Movement Exercise 1 helped the students understand how large behaviors must be broken down into smaller behaviors. For example, drawing a picture requires rotating the robot to form corners and curves and pushing a button will start the robot. Movement Exercise 2 helped the students understand *If-Else* statements and the cause and effect of button pushing and drawing a picture. Movement Exercise 3 helped students to be able to code emotions by having the lights on the tortoise blink to represent thinking. Movement Exercises 4 and 5 helped students understand how they might program their robot to use materials such as paper and markers and evoke emotions of happiness when they saw the completed drawing.

The Babushka: The Robotic Russian Grandmother with Emotions

Description. The students from this group built a robot that expressed emotions and reactions (see Image 8.3). The robot was constructed with a wheel on the bottom, a long rectangle for the face and body, metal arms on either side, and had a headscarf tied on its head. This scarf reminded the students of an old, Russian grandmother, hence its name (Babushka literally means grandmother in Russian). Below is a description of what emotions the robot was programmed to express and how it expressed them, taken from the students' journals.

The robot will express sadness, excitement, and anger, and it will do a dance routine. It will express sadness when someone gets far away from it, excitement when someone gets closer to it. It will express anger if someone touches its light sensor and will do a dance when someone presses its button.

The robot will express sadness with blue lights, a long, low beep, and moving slowly forward. The robot will express excitement with a long, high beep, moving

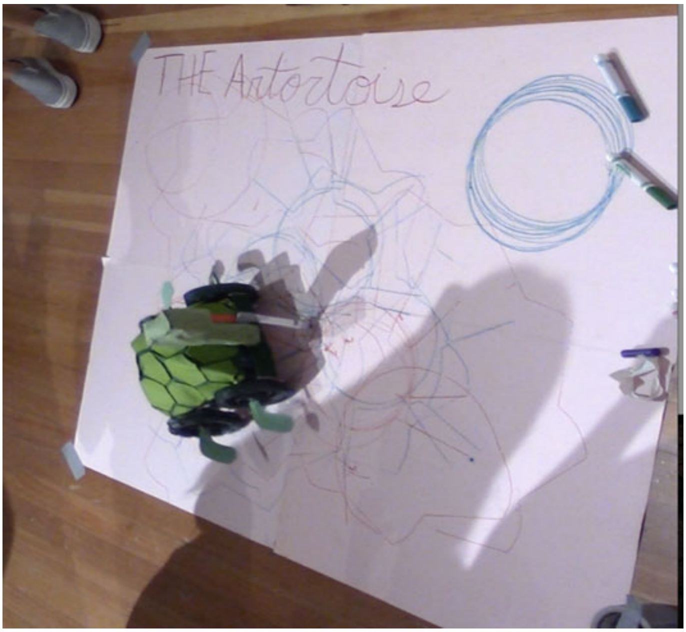


Image 8.2 Artortoise

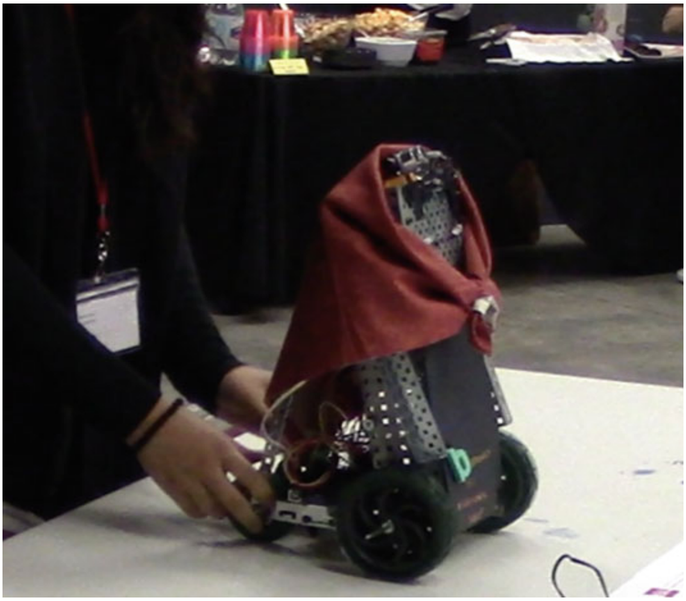


Image 8.3 Babushka

backward, and flashing white lights. It will express anger by moving back and forth flashing red lights and letting out short, low beeps. The robot will express [sic] the dance routine by flashing many colored lights and playing the tune of “Stayin’ Alive.”

Coding Connections. The Babushka had one code that drove most of the movements. *If* the sensor noticed someone is getting far away, *then* it would express sadness. However, *if* the first sensor was not activated, the *else* code would verify *if* the second sensor was activated. Otherwise, *if* the second sensor was activated, *then* the robot expressed excitement. *If* the second sensor was not activated, the *else* code would check whether the third and final sensor was activated. *If* so, *then* it would activate anger.

Direct connections of their coding can be made to various movement exercises. Movement Exercise 1 helped the students understand how large behaviors had to be broken down into smaller behaviors. For example, in order for the robot to express anger, it needed to have the light sensor touched. If so, it moves backward and forward and raised both arms. Movement Exercise 2 helped the students understand *If*-*Else* statements and cause and effect. Movement Exercise 3 helped students code for emotions. Movement Exercises 4 and 5 helped students understand how their robot could use materials, such as its lights and arms, to express different emotions.

Conclusion

In response to shifting economic forces that demand twenty-first-century thinkers, we applied STEAM principles that call for the integration of art into STEM teaching and created a curriculum framed by the concepts of the theories of embodied cognition and analogical reasoning. Based on prior research, we believe that embodied cognition is an appropriate framework for a robotics curriculum for two main reasons: first, embodied cognition guides much of robotic design and research; and second, there is evidence that "human bodies can be used for all sorts of cognitive purposes" (Kirsch, 2013, p. 327). We employed principles shown to scaffold analogical reasoning in order to promote HOT skills, such that students were drawing connections between expressive movements, coding, and robot creation. The curriculum that we have designed has been well received by our students and the products that have been made as part of our classes showcase tremendous talent, creativity, and solid understanding of robotics. More importantly, the students who graduated from our program demonstrated their readiness for the modern STEM workplace, and their ability to contribute as twenty-first-century thinkers.

We argue that not only does engaging in STEAM provide learning opportunities for the future STEM workforce, it also provides an opportunity to reimagine how students engage in humanistic science. This curriculum shifts and turns to include humanistic ways of "thinking and doing" by integrating the arts into STEM, utilizing principles with high relevance, and connecting artistic movement and HOT skills, embodied cognition, and analogical reasoning. Through this transition, we aim to redefine the human experience of engagement in science as a lived experience through a shift in beliefs. There is a shift toward an epistemology of hope in doing science for people while engaging with people, such that learning about science is more democratic and humanistic.

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Chapter 9
Embracing Creativity in K-12 Engineering Pedagogy

Alestra Flores Menéndez and Helen Min

Abstract This exploratory chapter proposes placing an explicit focus on creativity as part of K-12 STEAM education, specifically within the context of engineering. We examine how three key elements of an applied arts pedagogy, promoting divergent thinking, reframing failure as a natural part of the creative design process, and incorporating reflection, can enrich the engineering design cycle. We propose that broadening the scope of engineering education to foster creativity may have the potential to attract a larger number of participants to the discipline of engineering.

Introduction

The mission to educate a pool of informed, career ready citizens for the fields of science, technology, engineering, and mathematics (STEM) has fueled legislation and funding in support of STEM education (Gonzalez & Kuenzi, 2012). The Next Generation Science Standards were recently developed to guide national science education curriculum and assessment. The NGSS emphasize understanding the practices of science and engineering and call out key conceptual knowledge students will need to engage in the STEM fields. Much of the current push in education policy around STEM education is in part a reaction to student performance. When comparing US students against international standards of achievement, students in the USA show a troubling lack of science and math proficiency, and it has been recognized that students in the USA show a troubling lack of science and math proficiency (Kuenzi, 2008). Compared to youth in other nations, 15-year-olds in the US ranked 28th in math literacy and 24th in science literacy. In the technologically driven twenty-first century, proficiency in mathematics and science are necessary (Gillen, 2014). Yet, we must proceed with caution when considering proposed educational reforms to

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address the assertion that we are “A Nation at Risk” (Vinovskis, 2015). Educational reforms and pedagogical practices developed to address student achievement in our nation must consider larger social issues that directly impact academic achievement. The disparity of minority ethnic groups and women in STEM fields calls for an investigation of accessibility; this also connects to the larger underlying issue of language access in education and equally preparing all students for the real-world applications of STEM, which are relevant and critical regardless of the specific career path they may choose to take (Babaci-Wilhite, 2013; Milner, 2015). This chapter examines how a STEM pedagogy that includes the arts, or STEAM, might motivate diverse learners and potentiate the inclusion of underrepresented groups. We focus on ways in which a studio thinking approach that places an emphasis on creativity can enrich STEAM education. In this chapter, we will examine definitions of creativity and practices used to explore how these might apply to an engineering education context. Specifically, we will consider how studio habits of mind can be effectively incorporated into the engineering curriculum to bolster creativity and inclusion.

Explicating Creativity

Creativity is a universal human pursuit. As Simonton (2000) states that creativity is certainly among the most important and pervasive of all human activities. What is important for our exploration here is examining creativity as a methodology that empowers learners to be thoughtful and efficacious (Kelley & Kelley, 2013; Sternberg, 2008) in the context of engineering. We look to pedagogical practices that embrace and nurture what Kaufman and Beghetto (2009) explain as the creativity that underlies the learning process.

Varied definitions of creativity exist across disciplines and can contradict one another. For some, novelty and usefulness are primary criteria, and for others, it is the ability to form analogies, while some require an element of surprise (Kaufman, 2013; Torrance, 1988). Many scholars propose that to be creative there must be generalizability across domains, yet others believe that creativity is domain specific (Torrance, 1988). Creativity experts do tend to agree that creativity is a process (Kelley & Kelley, 2013; Seelig, 2012; Robinson, 2006). Drawing from empirical observations and accounts of famous inventors and polymaths, Graham Wallas pioneered a model of the process of creativity (Popova, 2016). In the *Art of Thought* (1926), Wallas proposed that there are four parts to the creative process: preparation, incubation, illumination, and revision. Building upon Wallas’ model, Sternberg (2008) lists the following elements as part of the creative process: redefining problems to seek out solutions, taking sensible risks, accepting failure as part of the process, confronting obstacles when challenging the status quo, tolerating ambiguity, and continuing to grow intellectually.

For the purpose of exploring, a pedagogical approach to integrate creativity in engineering education, we synthesize the findings of Wallas and Sternberg and employ a definition of creativity as a process to conceptualize novel ideas and to see connections among seemingly unrelated things, also known as “divergent thinking” (Connor, Karmokar, & Whittington, 2015). We will examine how an emphasis on creativity can enrich kindergarten through high school (K-12) engineering education by promoting divergent thinking and inoculating against failure. We will also consider how an explicit focus on reflection can tailor the creative process for diverse learners and make room for aspirational expectations.

Creativity in Engineering Pedagogy

To foster creativity, students must be provided with authentic opportunities to inspire motivation and reflection (Kaufman & Gregoire, 2015). Furthermore, students must be given opportunities to engage in both divergent and convergent thinking. For example, when defining engineering problems or imagining solutions, it is beneficial to engage in flexible thinking to generate a large and varied pool of ideas (Gilhooly et al, 2007; Seelig, 2012). At other stages of the engineering process, it will be important to use focused or convergent thinking for evaluating the best ideas and solutions. Therefore, it is necessary to demonstrate the value of both spontaneous and controlled thinking (Kaufman & Gregoire, 2015), and at which points in the process it is beneficial to engage in a particular kind of thinking.

We take on the view that essential aspects of creativity can be taught as a part of engineering instruction. While some aspects of creativity extend beyond the classroom, we propose that pedagogical approaches around thinking creatively can motivate student engagement with the practices of engineers, to think more expansively and to build a resilience against failure. This kind of mental flexibility and persistence are required for creative problem solving (Kaufman, 2013).

STEAM curricula in K-12 education are a relatively recent phenomenon. In this burgeoning field, creativity is acknowledged as part of the engineering process; for example, Katehi, Pearson, and Feder (2009) identify engineering habits of mind to include the following:

- Systems thinking;
- Creativity;
- Optimism;
- Collaboration;
- Communication;
- Attention to ethical considerations.

This contradicts with the pervasively held perception that engineers are not creative or that engineering does not involve creativity (Kazerounian & Foley, 2007). This extends to post-secondary engineering instruction as well (Kazerounian & Foley, 2007). Thus, efforts to include creativity as an explicit part of K-12 engineering curricula directly challenge long-held perceptions about the role of creativity in engineering education. We confront this challenge by carefully examining how the studio habits of mind can span and unify the fields of engineering and art.

Incorporating Studio Methods

The arts have a well-defined and well-established methodology for nurturing creativity (Little & Cardenas, 2001; Boy, 2013; Connor et al., 2015). Creativity is placed firmly at the nexus of art education and practice. The Studio Thinking Project of Harvard University's Graduate School of Education developed a multi-year investigation to examine how teachers design instruction around the arts and what students learn. Researchers sought to find out if thinking dispositions are inculcated through the application of art techniques and how these habits of mind could predict the transfer of creative thinking outside of the arts (Winner et al., 2006). Applying this inquiry to the engineering design process may help us identify parallels between studio thinking and engineering education. How can this cognitive framework spur creativity and innovation, and if so at what point in the design process should this kind of thinking to be promoted and supported?

In Fig. 9.1, we compare the 8 Studio Habits of Mind cultivated from serious art study with engineering practices as described in the Next Generation Science Standards (NGSS) and find several parallels.

Yet there are three remaining studio habits of mind that if incorporated to engineering education K-12, have the potential to greatly enhance creativity when designing solutions to problems.

1. Learning to attend to visual contexts more closely than ordinary "looking."
2. Stretching to reach beyond one's capacities, exploring playfully without a preconceived plan, and embracing the opportunities to learn from mistakes.
3. Reflection and learning to think and talk with others about an aspect of one's work or working process.

Here we discuss how these three studio habits of mind so essential to creativity can be incorporated into the practices of engineering by (1) promoting divergent thinking, (2) replacing failure with curiosity, and (3) incorporating reflection to the process of learning.

Promoting Divergent Thinking

Divergent thinking or the generative ability to produce several novel solutions to a problem is often used in psychometric measurements of creativity (Andreasen, 2005). For the field of engineering education, it may prove advantageous to place an emphasis on divergent thinking within NGSS practice 6: designing solutions to problems. Providing students with an exploratory period to generate ideas could provide for autonomy, inspiration, passion, curiosity, and a lit up imagination identified by Sir Ken Robinson as necessary for the development of creative capacities (2006). Divergent thinking could potentially improve student engagement with NGSS practice 1: defining problems. Providing a space for context broadening early in the process enables learners to challenge assumptions and encourages divergent thinking during the framing of problems (Seelig, 2012; Connor et al., 2015). This type of generative thinking enables a wide range of students to engage with the learning process without a preconceived plan (Keating, 1980) early on. This kind of low stakes exploration also allows students to exercise comfort with ambiguity, which may facilitate learning from mistakes (Little & Cardenas, 2001; Connor et al., 2015).

Allowing for an open exploration of ideas is particularly fruitful when students are provided time and space to engage in different kinds of mental processing. Neuroscientific findings indicate that while students are working on other unrelated tasks, the default or imagination network of their brains might be at work, a phenomenon known to yield proverbial *Aha!* moments of clarity in problem solving (Kelley & Kelley, 2013; Kaufman & Gregoire, 2015; Oakley, 2014). During the framing, imagining, and planning stages of the engineering process, it may be important to acknowledge that experimentation and creative ideas that do not work in the short term may lead to greater understanding in the long term (Connor et al., 2015). To promote divergent thinking, emphasis should be placed on generating a large number of ideas while

Studio Habits of Mind (Harvard Graduate School of Education)	**Engineering Practices (Next Generation Science Standards)**
Learning to use tools, materials, artistic conventions	Using tools and materials
Embrace problems of relevance within the art world and/or of personal importance, to develop focus conducive to working and persevering at tasks	Defining problems
Picture mentally what cannot be directly observed, and imagine possible next steps in making a piece	Developing and using models
Learning to create works that convey an idea, a feeling, or a personal meaning AND Learning to interact as an artist with other artists	Obtaining, evaluating, and communicating information

Fig. 9.1 A comparison between the 8 Studio Habits of Mind cultivated from serious art study with Engineering Practices as described in the NGSS

withholding judgment. This accords with the advice of Nobel Laureate Linus Pauling, "If you want a good idea, start with a lot of ideas" (Crick, Byrne, & George, 1995). When learners are not deterred by the fear of failure, they may be able to generate more ideas and more novel ideas.

Buffering Failure

In the effort to encourage and foster divergent thinking in students, engineering education must reframe student perceptions of failure to result in the most effective solutions. "Failure" must instead be recast as part of the engineering process. Students should participate in engineering tasks in which the imperative is to generate multiple or alternative solutions prior to placing an emphasis on evaluating for the most effective solution, which calls for convergent thinking. In this way, a K-12 engineering curriculum can destigmatize so-called failures and reframe these as generative of alternative possibilities.

One approach is to invite students to replace the fear of failure with the drive for curiosity (Kaufman, 2015). For example, modeling for students how the "failure" resulting from repeated attempts to solve a problem can actually uncover interesting and novel ideas (Kelley & Kelley, 2013). Another important habit of mind is grit, which can ward against the fear of making mistakes (Duckworth, Peterson, Matthews, & Kelly, 2007). Equipped with this mindset, students could "set their sights higher, try harder, persevere longer, and show more resilience in the face of failure" (Kelley & Kelley, 2013). Students can be made aware that failure is, in fact, necessary and even inevitable in the path toward success; and that those who succeed in problem solving have simply made more attempts (Kelley & Kelley, 2013; Simonton, 2006). Establishing a pedagogical model that embraces creativity would move students away from the idea that "mistakes are the worst thing you can make" (Robinson, 2006) and move them toward understanding that a willingness to make mistakes is what encourages originality and productivity in engineering.

Reflection for Learning

Reflection is also a key part of the engineering process. Students deliberately think through, in talk or in writing, what they have tried so far and what results it has yielded; this stage is recognized as an essential and deeply effective part of the learning process across content areas (Stohlmann, Moore, & Roehrig, 2012; Kolb & Fry, 1974). The immediate application of new knowledge coupled with reflecting upon the engineering process enhances creativity by continually considering "what next?" Hetland points out that the *import paradigm* employed in the studio method stresses applying new knowledge immediately in a serious way for a complex and significant endeavor (2013). This just-in-time instruction model for learning invalidates the just-in-case model of warehousing knowledge for the future (Hetland, 2013). Reflecting on and applying these insights can propel students toward finding effective solutions while also discarding ideas they have found ineffective.

Because engineering entails as a multi-step, iterative process, it is important to guide learners to reflect upon process and purpose. Reflection is central to the studio thinking method where students are continually pushed to think about what they are doing, and why they are doing it (Hetland, 2013). Kolb suggests that there are two parts to a reflective process: reflective observation (direct reflection) and abstract conceptualization (summing up the meaning) (Kolb & Fry, 1974). With this in mind, students should be guided to explicitly and deliberately think through and record what they experienced firsthand and then what has been learned as a result of this experience.

Continual reflection throughout the engineering cycle can help students identify the practices of engineers they have employed, and it allows them to understand how and why they engage in these practices. Reflecting upon when to use which mode of thinking, flexible, or deliberate can also help students engage purposefully with the various stages of the cycle. Through this practice, students can develop the metacognitive awareness necessary to deliberately switch between flexible thinking and a more focused and intentional thought process at different points in the design cycle.

Conclusion

As K-12 engineering education is still in active development, this presents an opportunity to forefront the role of creativity as a practice inherent in the process of engineering in STEAM education and to embed these practices in curricular approaches (Kim & Park, 2012; Park & Ko, 2012). By learning from the creative process and "studio habits of mind," we can encourage students to develop multiple solutions to a problem and encourage complex and developed thinking (Little & Cardenas, 2001). In fact, in traditional post-secondary engineering education, students would also benefit from encouragement toward divergent thinking, embracing failure, and reflection, rather than pedagogical approaches that are focused on receptive and passive student learning (Connor et al., 2015).

The atmosphere of K-12 education in the USA has been largely impacted by a rigid adherence to standards and assessments. Educators and students are pressured to "perform," and this may also inhibit creativity while emphasizing conformity. By transforming the methods of assessment to include emphasis on creativity and de-emphasizing the importance of a single correct outcome, learners can take up the habits of mind necessary to address real-world problems: aspirational objectives and positive affective responses to failure.

In a K-12 engineering curriculum where failure is embraced as potential opportunity, students can further cultivate a growth mindset (Dweck, 2006). When assessments for learning incorporate measures such as generating multiple solutions, engaging in flexible thinking and creative problem solving, students are freed from the constraints of generating a single right answer. Most importantly, placing value on diverse ideas and perspectives can invite a broader group of participants to the field of engineering. Further, investigation is necessary to examine how embracing creativity in K-12 engineering pedagogy can improve accessibility to the field of engineering and how diversifying the field of engineering can impact the outcomes of this field.

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Chapter 10
Notes from Artists: Making the Invisible Visible and Art as the Bridge to Science and Interconnectedness

Liz Ibarra and Ane Sommerstad

Abstract This chapter is a meditation on the relationship and development of art and science. Both disciplines are born out of our innate need for answers to the mysteries of life. Seeking those answers leads us to create solutions, innovations, and works of art that propel us into the ever evolving future. Natural science informs the philosophy; and the way art and creativity is a result of the influence of aesthetics, physics and biology.

Making the Invisible Visible

I have often heard about the scientific-artistic divide. It has never rung true to me. I don't believe there has ever been a divide. Art and science have been inextricably linked throughout history. They are two aspects of a mysterious universe, two sides of the coin of observation. Did one beget the other? Did art beget science? We observe the world and keep trying to understand it, to unravel its mysteries, to explain it to ourselves and others.

I am going to talk about the many similarities between artists and scientists. There are similarities in perception, in methodology, symbology and execution. Art creatively asks the eternal questions, and science attempts to answer them. Both artists and scientists are investigators. In observing the world around us, we somehow intuit that there is something beyond what we see. Something invisible, unknowable, beyond our cognitive abilities. This inspires awe and wonder, which inspires ideas and hypotheses, which inspires experimentation and movement.

Laboratories and studios serve the same purpose—the investigation of the complexities around us. Because of that, we necessarily become students. Students of

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life primarily, but we also study physical objects, people, cultures, history, religion, psychology, in other words, everything we can, in order to interpret the phenomena we are surrounded by. All of this information is transformed and something new, and sometimes revolutionary, emerges. It happens because we do not fear the unknown. We try to understand what we don't know, no matter how absurd or dangerous it might seem. In effect, art and science have the same goal—to change our perception of the world. From the time an early human put his handprint on a cave wall, we have been attempting to make our state of being visible. We are driven to create Art.

Experience and the life force combine to stimulate our questions and ideas. Observing the vastness of the heavens and watching the movement of stars and planets gave birth to ideas. Art and science are thus born. We made tools and they went beyond their basic functions to become materials used to create. Human cultures arose out of the need to experiment, experience and learn. Our ingenuity and brain power suggested not just pictographs and sculptures; it took us further, to the creation of Mathematics and Astronomy.

Our consciousness is constantly prodded by our unconscious mind to answer questions and doubts as concretely as possible. To an artist, these are "answered" by allowing the creative process to take over. I think the same thing can be said of scientists. Science is not purely rational. It depends as much on inspiration, imagination and intuition as any form of art. Looking at the stars and their position in the skies prompted the naming of constellations. We had no idea what stars were so they became gods, animals and objects; an exercise in creative thinking. The workings of the universe are cosmic and abstract, so we try to make order and systems out of the invisible chaos. What began as something supernatural gradually became empirical. What started out as natural philosophy became hard science. Often it happened through serendipity and chance.

Through the search for impossible answers, through dreams, or odd juxtapositions. Creativity is at the heart of both art and science. So the growth and development of art and science were precipitated by finding ourselves in a world of inexplicable mysteries. What is this planet we live on? Why do we have night and day? What exists in the skies or under the seas? What is air? How do we think? Why do we create? These are some fundamental questions that have led us to where we are now. These investigations, both physical and mental, have revealed that the earth revolves around the sun. That gravity, an invisible force, exists and that everything on earth is subject to that force.

We have learned that natural selection is responsible for evolution. We have discovered atoms and curved spacetime and black holes and an expanding universe. Einstein said there is no logical way to the discovery of these elemental laws. There is only the way of intuition, which is helped by a feeling for the order lying behind the appearance. A renowned scientist, a physicist, is talking about intuition, feelings and what lies behind appearances. That seems awfully artistic of him! I personally find Einstein and his theories highly inspirational. Even though I find it difficult to articulate exactly how physics has influenced my Art, I intuitively know it has. The uncertainty principle has played a big part in my own creative awareness. Is it a particle or a wave? It is both, and that has opened the door to unlimited possibilities for me. I never know what's going to sneak out of my unconscious, as it combines with my personal experiences and experimentation.

I am a naturalist. My own art has been greatly influenced by nature and its wonders. I was born in a country of tropical forests, exotic flora and fauna and active volcanoes. These phenomena are both latent and overt in my work. They have steered me toward the natural sciences. I am fascinated by biology, entomology, oceanography, to name a few. These interests have helped me manifest patterns and images from my unconscious and develop them into something perceptible and recognizable, and I hope, into something meaningful. I have been preoccupied with nature all my artistic life.

The methodology of artists and scientists often overlap. Both can be equally obsessive in their pursuit of results. Sometimes these experiments work, sometimes they fail. But we never stop. My art is informed both consciously and subconsciously by the principles of science. There are many disciplines and theories involved in creating. Art theory has a mathematical correlation.

Symmetry exists in art, mathematics and in physics. Whether we call it time translation, translational, or rotational, it is there to guide us in the production of something beautiful.

An obvious example of an artist immersed in science is Leonardo Da Vinci. Even his perfect human form was modeled on the proportions laid out by Vitruvius, an ancient Roman architect. Da Vinci made great contributions to the foundations of science. He could be called one of the first urban planners. He believed that the study of science made him a better artist. And of course, we know of many scientists who were also painters, musicians, poets and writers such as Isaac Newton, Audubon, Samuel Morse, Goethe, Lewis Carroll and Beatrix Potter. The list goes on and on with many contemporary artists who are also physicists, doctors, botanists, to name a few.

Another shared goal of both art and science is making and understanding connections. As we understood the interconnectedness of humans, we created societies, which established shared values and ethics based on observation and knowledge. One of the basic tools to help us achieve connection is language. Language is a necessity in order to express ideas. We want to be able to express and communicate the basic concepts of reality (that which we observe) to the ineffable (that which we imagine). As language is developed to express, it also motivates further, more precise observation and expression. The more literate we become, the more complex and incisive our expression.

Language induces thinking. We read, we write, we organize our thoughts and we engage in discourse. All of this helps engender critical thinking. Critical thinking leads to deeper thinking, deeper inquiry and imagination, ultimately, deeper discovery. Critical thinking is crucial in a world of intricate systems and their problems, which will require creative and difficult solutions.

Beyond the oral or written languages we know are the languages that cross all barriers. These are the universal languages of the visual arts, music and mathematics. They can be experienced and understood by anyone, anywhere. They are the languages of the senses, of the mind and spirit. They are also useful tools of inquiry in the search for evidence that underlies every scientific or artistic endeavor.

In a world where the rational is overvalued, art provides us with both the physical and the metaphysical fulfillment of our creative needs as humans. Our imaginations require release and freedom. We know that creativity alone is not always enough. In order to manifest our ideas, we have to have a foundation. We learn techniques, we use certain tools and we study those subjects that fuel and develop our imaginations. We have to acquire some discipline within ourselves as we study the different subjects we need, in order to execute ideas. So it is in art, so it is in science. W. I. B. Beveridge, A Cambridge University professor of animal pathology, wrote a treatise on creativity in science called "The Art of Scientific Investigation" arguing that while imagination is the source of inspiration in seeking new knowledge, it can also be dangerous if not subjected to discipline; a fertile imagination needs to be balanced by criticism and judgment. This is, of course, quite different from saying it should be repressed or crushed. The imagination merely enables us to wander into the darkness of the unknown where, by the dim light of the knowledge we carry, we may glimpse something that seems of interest. But when we bring it out and examine it more closely, it usually proves to be only trash whose glitter had caught our attention. Things not clearly seen often take on grotesque forms. Imagination is at once the source of all hope and inspiration but also of frustration. To forget this is to court despair. I think this idea applies more to the scientific processes, since artists have a higher tolerance for trash, danger, despair and the grotesque! But both artists and scientists often find themselves wandering into the darkness of the unknown. Again, trying to make the unknown or invisible, known and visible. Here is where education comes in, education gives us the training and skills we need to harness our ability to discover and create. To think critically and not be seduced by the "glittering trash". The Sciences and their disciplines are rooted and entwined in the real world, where they serve to solve the deep and complex problems that face us. Education helps us arrive at and implement those solutions. Education gives us the background to comprehend and further our evolution. It enables us to speak the languages that we need to communicate and innovate. A foundation in the sciences is necessary for the world we live in, but the future requires another leap into the unknown. It is also not just about academics. Education helps cultivate order, discipline and logic but without creative ideas where does it go? That is where art is essential. Not only do we need to be well balanced, we need creativity to drive us toward the discoveries that await us. Art brings with it an unfettered viewpoint that sparks innovation. Rationality and logic are just part of the picture; aesthetics make the picture beautiful. Art opens the door to the divine. The divine within us and around us. The invisible made visible.

Art as the Bridge to Science and Interconnectedness

> Can a greater integration of art in STEM give the STEAM needed for a continuous development toward a more sustainable direction in several fields?

Since the beginning of our presence on earth, there has been a human drive to understand the world. Visual expressions such as the first rock paintings in Southern Africa, which date back 70,000 years, alongside sacred rituals, dances, myths and music, are expressions of humankinds' need to connect to a larger picture. We have striven to make sense of what we do not fully comprehend, whether the changing seasons, animal migration, moon cycles, or stars constellations. It is the mystery of our being that compels us to understand and explain, to gain clarity and embrace life's complexity. It is a search for inner and outer perspective, a never-ending cycle of contraction and expansion.

Art plays a big role in embracing this process. The introvert process of the artist aims to grasp and express existence in order to transform it from the immaterial to the material. As STEM subjects in essence follow the same cycle, creativity can bridge this process from inward to outward. As humans we have the need and ability to break out of current circumstances, group or social norms, into new paradigms and expressions.

Cultivation of fire was the turning point for a new era in our history, being the foundation for making new kinds of tools and cultivating nature to a much larger extent. Another big shift came about as technology started to effect the development of our society. Without fossil fuels and petroleum products, the development of this last and in many aspects troubling era would not have been possible. They have enabled us to conquer previously unhabitable territories and build space ships. Has science and technology, at least in the "West", taken over the role of "storyteller" from art in our quest to understand the mystery of human existence? Has the new era of science and technology focused on rationality and reason at the expense of intuition undermined our understanding of holistic connectedness?

We are now at a time in history where our course has to change in order to address the global environmental crisis. We need a renewed understanding of our co-dependency with nature. Art has always played an important role in challenging conventional beliefs and morality, and as a catalyst for change.

In my Art, I am deeply concerned about our callous exploitation of nature, other races, and nations, and about our loss of mysticism and wonder. We cannot continue making a uniform "Westernized" elitist culture the dominant approach for our understanding of the world. I have explored my role as an artist deeply, not from an intellectual point of view but more from a desire to be a catalyst and build bridges. I only feel justified to create an ecological footprint from my work if it works as a catalyst for reconnecting us to the mystery of being and to our very roots. My sculptural messengers and art are a bridge between the worlds of the purely rational mind and the experience of being connected and a part of an omnipresent energy of existence.

Title: Endless listening

Art can reinforce its role as a communicator of omnipresence, as well as a way of gaining and integrating a greater creative spark. Integrated in the STEM subjects, Art would help create a more open field. If we are to access a higher potential and awareness of a much bigger picture, incomprehensible by the rational mind, we need ways of activating other senses. These senses are needed for the creative process, which constantly moves between chaos and order, between control and release.

Let Us Rethink Technology

Through modern technology and our evolution, we are regaining awareness of our connection to something larger than ourselves. This sense of belonging is what I aspire to activate through my art. By bridging the modern with the primal existential belonging, we can tap into a collective field of consciousness that moves through time and gain access to knowledge not limited to the mind alone.

Title : I Am

Through tapping into this greater field, where connectedness to nature and all existence prevail, we will move beyond social and cultural distinctions and separateness. True evolution moves in both directions through time in a non-linear way. Art can, in my opinion, enhance this vast field of possibilities. The connectedness to everything that was present in the early humans and still is in many indigenous groups, made existence sustainable for thousands of years.

When we are empathetic to a wider field through a creative process, I believe it is much harder to discriminate against, exploit and justify control over nature and other people. Doesn't all new innovation start as an immaterial vision, an inspired idea, a question, an intuitive spark that inspires investigation, trial and errors and the whole creative process in order to materialize something? In this sense, the broader the field of backgrounds and cultures that can be activated in the field of creation, the more interesting the results.

To be co-creators in shaping evolving reality, the STEM subjects should connect to Art to unleash an immense potential to meet our current need for more holistic solutions and innovations beyond political and economic trends and power, and beyond limited perceptions of status quo. The foundation of the basic artistic process entails a movement from chaos to order, from construction to deconstruction until one settles on a final outcome, which then again has the potential to inspire a continued process in the viewer.

In my work, especially the sculpture project called The Fire Tribe (21 sculptures 2.7 m tall in scorched aspen, ceramic and horsehair) as represented in the picture below, I have connected deeply with the process of construction and deconstruction through fire.

Title: The Dreamcatcher

The sculptures were made from an imaginary melting pot of human diversities to bring about expressions that could connect us to our primal, existential belonging. Modern techniques and technology were connected in time by my use of fire, ashes, sewing, pigments and wax. Little did I know when I started out that this spark would change and speed up my life and artistic career, connecting me to people around the globe. My artistic approach and way of developing my career became a much more non-linear and expansive way of working and moving with my vision.

Title: The silence of Now

Title: Who am I ?

I now sincerely believe in the potential of artistic processes and creativity for investigating change at all levels, cultural, social and individual. Art can catalyze openness to knowledge and insights from minority and disenfranchised groups. If we dare to integrate art into STEM, we will offer students the STEAM necessary for co-creation and co-learning, thus equipping them to address the social, educational and ecological challenges the world faces. The more we embrace an interconnectedness between different subjects, people, cultures, types of knowledge and approaches, the more we can tap into the vastness and mystery of existence. Since we live in an ever-expanding field of understanding the world and the universe, where everything is inter-linked, education will have to catch up with this reality. When artistic creative processes are embraced in STEM, bridges can be built in ways we can not yet comprehend, and I am convinced that they will be more alignment with the fast-expanding consciousness in the world. If we continue in a conservative way of thinking in terms of separateness, whether it is racial, social, cultural, historical, natural and universal, we will remain at the station as the train leaves toward a place where limiting, non-holistic thinking is inevitably evaporating into oblivion.

Part III
Pedagogical Tools in Mathematics, Ethno-Mathematics and Medicine

Chapter 11
Humanity Moving Since Pre-historic Times to the Future with Creative STEAM

Ubiratan D'Ambrosio

Abstract In this chapter I go beyond the concept of STEM, to present in contemporary educational proposals for the entire world. The first strategies of the human species to deal with are natural facts and phenomena; these are generally embraced by concept of **Technology**. Early humans generated *ad-hoc* solutions to satisfy their needs for survival. From shelter to nourishment, these solutions were essential in the evolution of the species. The emotional evolution of the species led to generating *ad-hoc* solutions to satisfy their desire which transcend needs. Next, probably the turning point in the evolution of the species was to recognize that how to face an *ad-hoc* situation might be used in other similar situations. This means, recognizing that the "hows" constitute methods. This step leads to ask **why** and in which circumstances methods work. This is the quintessence of **Science**. Understanding how and why, humans venture into the new, imagining new representations of the real, thus creating **Arts**, and innovating with the introduction of new material constructs, thus creating **Engineering**. But Science required new intellectual instruments to understand the "hows" and "whys". These intellectual instruments gave rise origin to **Mathematics**. Thus, the evolution of material and intellectual instruments developed by the human species is the evolution of **Technology, Science, Arts, Engineering** and **Mathematics**. Even ignoring historical precedence, a central topic in Education is Science, Technology, Arts, Engineering and Mathematics or **STEAM**. STEAM is a response to natural and social environment and, together with mythology, the support of culture. I use a metaphor. STEAM was decisive for the emergence of the Industrial Era. Thus the metaphorical figure of the STEAM as the fuel that moves mankind to the future.

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Early Reflections on STEM and STEAM

In 1992, the National Science Foundation of the USA invited six scholars from different parts of the world—all with expertise in Science and Mathematics education—to participate in a four-week full-time working Symposium on International Perspectives on Science, Mathematics, Engineering and Technology Education. The project was designed by Dr. Kenneth J. Travers, Director of the Division of Research, Evaluation and Dissemination, with the endorsement of Dr. Luther Williams, Assistant Director, Directorate for Education and Human Resources. I was privileged to chair the group formed by Paul Black from England, Mohamed El-Tom from Sudan, Bienvenido Nebres from the Philippines, Tibor Nemetz from Hungary and Michael Matthews from Australia. Our task was to investigate current programs of these four fields of study at all levels of schooling and to review ongoing reform initiatives in Science and Mathematics education in the world and their global implications for the twenty-first century (D'Ambrosio et al., 1992).

The symposium was unique in several ways. Probably the most innovative feature was its interdisciplinary and international nature. Probably the most relevant conclusion was the recognition of clear indications that in the curricular designs of the future, Science, Mathematics, Engineering and Technology education will probably appear as a unified field of study.

Much of our work in the symposium dealt with the future. We tried to probe well into the twenty-first century as far as the year 2061 when Halley's Comet will reappear—into a future when today's children will be in charge and coping with the effects of our decisions. Given the accelerated pace of change and the increased interdependence of nations, the decisions we make today seem somehow more critical than do those made by our predecessors generations ago. During the four-weeks, we had the opportunity to meet with representatives of major professional societies, such as the American Association for the Advancement of Science, the National Science Teachers Association, the Mathematical Association of America and the National Council of Teachers of Mathematics and to interact with staff of the NSF.

More than ten years after this pioneering symposium, STEM became, as predicted, a major issue in Education, all over the world. By removing the traditional barriers between the four disciplines, STEM Education gives the opportunity to make sense of the world facing its complexity.

Although not explicitly discussed, the arts were permeating all our discussions. It was recognized that the development of communication skills should be taken further and enriched as children become acquainted with and developed appreciation of the Arts, including Literature, Music, Drama, Painting and Sculpture. An historical analysis and a careful understanding of these areas of knowledge reveal that art is intrinsic to all of them. This justifies moving a step further and discussing STEAM/Science, Technology, Engineering, Arts and Mathematics as a transdisciplinarian and transcultural proposal for Education.

The STEM Movement in Education: A Critical View

STEM, an acronym for "Science, Technology, Engineering and Mathematics", is an educational movement that is hoping to prepare youth for a competitive future. STEM does not simply teach Mathematics and Science skills in isolation, but encourages students to face and attempt to solve real-life problems through projects integrating multiple disciplines, hands-on experiences and higher order thinking. STEM aims at preparing innovative scientists and engineers who will provide the innovations vital to compete in the global world production, market and economy. As a consequence of the immediacy of the aims of the movement, Mathematics is relegated to a subsidiary role of support for Science, Technology and Engineering. It can not be denied that the technical, applicable and scientific aspect of Mathematics is important. But this is a very limited view of Mathematics. The History of all cultures and civilizations since Early Antiquity and even in pre-Historical times clearly distinguishes the Humanistic character of Mathematics. The intrinsic value of Mathematics, as a noble manifestation of human intelligence, is more important than its character of applicability and support to Science, Technology and Engineering. Mathematics has as its main objective to understand, to explain facts and phenomena of reality in the broadest sense, the state of mind of human beings, frequently appealing to myths, to language and to the symbolic and the spiritual. Mathematics is present in spiritual and religious practices, and Sacred Mathematics is well studied since Antiquity in every natural and socio-cultural environment. This is a higher intellectual dimension than its applicability that regrettably is not considered in the proposals of the STEM movement.

Mathematics in the curriculum must be broader. As educators, we have complementary roles of action in the classrooms and the promotion of the advancement of our discipline, since it is an instrument for the progress of humanity. This is true for every field of knowledge. To fulfill our commitments to humanity, we have to convey to students ethics in mastering these instruments. This asks for a critical view of their potentialities and of the risk involved in misusing them. We cannot avoid alerting children, through social and historical analysis, that Science, Technology and Engineering are prone to be instruments that may increase inequity, destruction and even war.

Undeniably, Mathematics provides an important instrument for social analyses. Western civilization entirely relies on data control and management. "The world of the twenty-first century is a world awash in numbers" (Steen, 2001). Social analysis is practically impossible without an understanding of basic quantitative Mathematics. But, quantitative Mathematics is not enough. I argue against an excessive emphasis on the quantitative. The quantitative aspect of Mathematics, embodied in skill and drilling, is defended in some circles of mathematicians and mathematics educators. This is detrimental to very important qualitative aspects. Data control and management may give false impression and interpretations without qualitative support.

Since Medieval times and the Renaissance, Mathematics became the key support of the emergent Modern Science and soon of Modern Technology and Engineering.

Recently, the multiple intelligences theories, especially emotional intelligence, spiritual intelligence and numerous approaches to cognition, including new developments in artificial intelligence and neurocognition, must be taken into account.

Preeminent mathematician Stephen Smale clearly defines his position about the intimate relation of Mathematics, the Sciences and Art:

> I tend to think that mathematics is more like art than other sciences. But there is one special difference, I find, which is that mathematics tends to be correct. Mistakes in mathematics are rarely significant for very long. But also mathematics tends to be more irrelevant. There is so much of mathematics that tends to go off in directions which are appreciated by a very few, irrelevant even to the rest of mathematics (Casacuberta & Castellet, 1992).

Smale raises several questions in the Philosophy of Mathematics, such as: how to decide on the relevance of mathematics? how universal is mathematics? what does it mean, in mathematics, to be "correct" and "rigorous"? An artist might paraphrase Smale, asking about relevance, universality and correctness of art. And the same can be asked of every form of knowledge.

I will address only the third question, in a different way. I ask if there is place for fiction and fantasy in Mathematics, as they are essential in the Arts?

Many say that this example is misleading, since it does not deal with objective reason. Indeed, as teachers of mathematics, especially in the STEM methodologies, we are told that we have to teach objective reason, to stimulate rational thinking in our students. But human mind is a complex of rational, emotional, intuitive, sensorial and mythical perceptions, involving all at the same time, with no hierarchy among these dimensions. They all come in an interplay and mutual influence. But there is much emphasis in the rational dimension, at the expense of the other dimensions, which sometimes are denied, even rejected and repressed. It is not uncommon to see a child punished for being "too happy" in the classroom. And we know of teachers saying to a boy "Stop crying. Men do not cry!"

It is not possible to build knowledge dissociating the rational from the mythical, the sensorial, the intuitive and the emotional dimensions. In the History of Mathematics, we recognize, in every moment, the conjugation of the rational, the mythical, the sensorial, the intuitive and the emotional. But regrettably, this has been conspicuously ignored in Mathematics Education and, indeed, even in the traditional, internalist History of Mathematics.

Fortunately, there has been a resurgence of interest in the intuitive, sensorial (hands-on projects) and in the affective aspects in Mathematics Education, including the spiritual and the mystical. Every aspect of individual behavior, every internal structuring, reveals both what comes from inside and what is contextualized. Both an inner voice and the motivation from the context and from the environment, in its broad cultural, social and natural senses, are partners in defining individual behavior. This leads to understanding the human condition. How is it possible to understand the generation and acquisition of knowledge by an individual, if not related to his behavior? Research mathematician and Mathematics educator Klaus Witz (2007) faces this question, with respect to spirituality and religion. The key point is the relation between knowledge and behavior, which I regard as the essence of the human condition.

The individual origin and the development of mathematical thinking are ignored. How do the motivation and needs, the emotional and inner feelings, the imaginary and fantasy and the mythical play a role in building-up Mathematical knowledge? What had Gustave Flaubert (1993) in mind when he wrote "Mathematics: the one who dries up the heart"?

Fiction deserves particular attention, since it deals with contemporary scientific advances in a narrative accessible to the general public and stimulates fantasy and creativity. It is recognized that fiction may be a support to create and to deepen historical understanding, even if it may come from pure imagination, from fantasy. Even coming ex nihilo, conscious and unconscious perceptions of reality underly fiction. According to Richard van Oort (1995):

> fiction appears to create a world *ex nihilo*, that is, it appears to defy normal conditions of reference that restrict conventional speech acts to an empirical world.

Indeed, even ideas coming *ex nihilo*, which are typical of fantasy, may lead to relevant mathematical creativity as clearly stated by the distinguished Norwegian mathematician Sophus Lie (1842–1899). In a letter written in 1893 to his friend Bjornson, Lie says:

> Without Fantasy one would never become a mathematician, and what gave me a place among the mathematicians of our day, despite my lack of knowledge and form, was the audacity of my thinking (Stubhaug, 2000).

The basic question is the relation of different forms of knowledge, in our case, how to relate Mathematics and the Arts. This needs a few preliminary questions: What is knowledge? How is it generated? How is it organized? How is it shared and transmitted?

A response to these considerations is explicit in the Program Ethnomathematics, which will be discussed further in this chapter. It is a broader vision of Mathematics, which aims at understanding human behavior in response to the basic needs of survival [common to every other living species] and of transcendence [only in the human species, so far not recognized in other species]. It leads, naturally, to reflections about Mathematics and the Arts.

In the struggle for survival, the species develop ways of dealing with the immediate environment, which provides air, water, nourishment, recognition of a mating partner and everything else needed for the survival of the individual and for the continuity of the species. These are ways and styles of individual and collective behavior used very simple auxiliary natural objects, recognized as useful. The human species went further and developed ways of sheltering, of controlling fire and of fabricating tools, with specific objectives, of raw materials, like flints. An example of a primeval step in fabricating more sophisticated instruments, an early step toward Technology. Another very important step in the emergence of the human species was the development of a sophisticated, very elaborate system of communication, language. Asking how and why was the most important step in the evolution of our species and it is the origin of reflective behavior.

Asking how and why is the first step toward going beyond survival, transcending the here and now. The human species developed perceptions of past, present and future and their enchaining, and means of explaining facts and phenomena. These means were the *technes* [arts and technics], such as memory, individual and collective, representations of the real [models], elaboration on these representations, generally called imagery, and the creation of myths, probing into the future through what I call, in general, the divinatory Arts. The organization of memories and myths resulted in history and traditions, which include religions and systems of values. The body of facts resulting from imagery resulted in the Arts. Modeling resulted in Engineering. The divinatory Arts gave origin to systems of explanations, such as Astrology, Oracles, Logia, the I Ching, Numerology and the Sciences, all with the object of telling us what will happen as the result of causes.

All these ways of human behavior are integrated as the result of pursuing survival and transcendence. In the pursuit of transcendence, humans developed strategies to quantify, qualify, classify and infer, and acquired capabilities which are called identify as numerosity, spatiality and sequentiality. These are essential in dealing with the concrete real world.

Equally important in the evolution of the human species was the capability of reasoning about representations of the real, amplifying into the imaginary. The transition of the concrete to the abstract is the acquisition of knowledge. These are the basic components which made possible both the Arts and Mathematics in the human species. Why this was only possible in the human species is an open and most intriguing question.

Art and Mathematics have been instrumental in developing both the means of survival and of transcendence. These developments follow different ways, patterns and styles, conditioned by the ethno, which is essentially the natural and social—cultural environment. Art has, implicitly, the recognition of the ethno conditioners. Both Mathematics and Art go together as strategies to cope with the reality and representations of reality in a given natural and socio-cultural environment.

The recuperation of knowledge of the people, particularly Art, is an important strategy for political awareness, which is a major goal of Education. It is important to transmit Mathematical knowledge, necessary for life in modern societies, based in multicultural reading of knowledge produced by the people, which is present and strongly represented in the Arts.[1]

The Way I Introduce the Concept of STEAM

The focus of my chapter is a historical reflection on the evolution of human behavior and knowledge, which results from the strategies of our ancestors to deal with reality and its representations. History gives hints on the ways living human beings, from

[1]This approach is adopted, with respect to blood and HIV, in the Project REPO history. Circulation, *Art Journal*, vol. 59, nº4, 2000, pp. 38–53.

birth to death, deal with these same issues in the present. These ways may be identified with STEAM, the acronym for Science, Technology, Engineering, Arts and Mathematics. Hence, the main focus of education, in all levels, must be to convey a perception of the emergence and the fundamental role of STEAM in every moment of human life.

The theoretical basis for my reflections is the Program Ethnomathematics, which will be briefly presented later in this chapter.

I avoid stating the exact meaning of the five categories—Science, Technology, Engineering, Arts and Mathematics. For the objective of this chapter, it is enough to assume the essence of their meaning and concept as generally understood in both academic and non-academic circles, the same as the concept of reality in a very broad sense. Occasionally, I appeal to some details about these categories for the benefit of the narrative, not as attempts of any kind of definition.

In the final quarter of the nineteenth century, Abbot (1884, 1984) wrote a beautiful fable, in which all creatures are planar. The *Square,* which is the narrator in Abbott's fable, was allowed to rise from the plane and to venture into the third dimension. Very much like the *Square*, men probe into higher dimensional spaces for explaining, understanding, predicting and creating. The immediate answer is the search of an *omni*-, an omniscient, an omnipresent and an omnipotent, whose habitat transcends reality. This is a step for overcoming the limitations intrinsic to life, metaphorically a planar reality. Religion emerges as the identification of such *omni*- which occurs in various possibilities, as single, multiple, near, away, concrete and abstract.

Human beings act according to intelligent strategies for knowledge and behavior, and enrich instinct, which is common to all species, with consciousness, seemingly unique to the species *homo*. In my narrative, I use the concepts of knowledge and of consciousness in different ways. They are all equivalent and the different choices, convenient for the fluency of the text, maintain the coherence of the narrative.

It is important to clarify, as it is clear from the discussions above, that I frequently appeal to fiction. Fiction and non-fiction are distinct forms of narrative, both aiming at discussing truth. The writers of non-fiction should not make up what they do not know and are limited to the universe of facts and by sources, rigorously accessed, frequently appealing to previous narratives and to references and citations of prestigious authors, endorsed by accredited institutions. The non-fictionist, sometimes timidly, appeals to intuition or suspicion, always very cautious to avoid censorship of peers. Instead, the writer of fiction is not subjected to these limitations. He can give space to his own imagination, even appealing to *ex nihilo* arguments. I indulge in both forms of narrative, non-fictionist and fictionist, in my attempts to analyze what may have happened in the past and to build coherent narratives of past scenarios.

This is particularly important when I try to understand and to explain how the species *homo* generated, organized and transmitted, both individually and socially, the strategies of to respond to the **pulsion of survival**, essentially how to stay alive and to guarantee the continuation of the species, and to the **pulsion of transcendence**, essentially why these strategies work: reflecting, understanding and explaining them. I see the satisfaction of the pulsions of survival and of transcendence the quintessence of being human.

There are evidences that life in the planet Earth dates back to about 4 × 10 years (Abbot, 1884, 1984). Life is characterized by the capability of continuity through self-reproduction. About ten years (Ibid) ago occurred sexual differentiation of more complex forms of life and are evidence of early forms of animal life about half a billion years ago. The early hominids appeared about six million years ago, maybe with the emergence of the *Orrorin tugenensis*, whose fossil was found in Kenya's Tugen Hills, considered, by inconclusive evidence, to probably be the first bipedal hominin species. Every once-a-while fossils are unearthened and provide new elements for controversial theories of human evolution. The *Australopithecus,* which existed from 4 to 2 million years ago, evolved as *homo erectus,* migrated out of Africa about 2 million years ago, and spread throughout Eurasia and to other regions of the planet. In these regions they evolved, leading to, among others, the species *homo neanderthalensis*, which lived approximately from 400,000 to 40,000 years ago in Europe and Asia. This species adapted to colder environments and lived in shelters, mainly caves, made and wore clothing and controlled fire. They hunted large animals and developed tools and instruments. They buried the dead and made ornamental and symbolic objects. It is even possible that they practiced cults and developed myths. This is the emergence of symbolic thinking. The species *homo sapiens* evolved in Africa about 200,000. They gathered and hunted food and moved extensively to look for more favorable environments. Eventually, they reached Europe and Asia and coexisted with *homo neanderthalensis* for at least 10,000 years and could have shared habitats in what must have been a complex relationship, involving competition and possibly some interbreeding. There is growing interest in learning more about Neanderthals. Particularly, interesting are recent results about symbolic and ritualistic behavior of Neanderthals, which places the origins of Art and the emergence of myths at about the same time as the origins of early tools. The *Howiesons Poort* culture, that flourished about 60,000 BC in the Eastern Cape province in South Africa, is an example of lithic technology and the emergence of decorative arts, characteristic of early symbolic culture and even shows a protomarket as an exchange of gifts with symbolic meaning of is. In other words, survival and transcendence have been together since earliest signs of intelligent behavior in our species, particularly through Art. It is unreasonable not to consider STEAM.

In the human species, action manifests, basically, in two ways:

- actions which lead to survival of the individual and of the species, and the satisfaction of needs, common to all living beings, which are performed in the instant; this I call the pulsion of survival;
- actions which satisfy man's needs for explanations, for understanding, for prediction and for creating, in response to will, which lead to transcend the instant and to search the past and probe into the future; this I call the pulsion of transcendence.

The species *homo* seems to be the only one that developed a sense of past and of future, transcending the present. As stated above, human species are characterized by the association of the pulsions of survival, common to all living beings, and of transcendence, unique to the human species. With the emergence of the species *homo*, tools, instruments, equipment and techniques came into playing a role in the relations between individual, other/society and nature.

Knowledge in the human species is recognized in the acquisition of abilities, capabilities, ways of doing, of explaining, of understanding and of coping with everyday needs for surviving, which leads to invention of different instruments transcendence, and takes the form of distinct ways of transcending, which leads to representing and communicating natural facts and phenomena. The representations are a primitive form of art. Gregariousness leads to the acceptance of distinct ways of organizing groups, of dividing labor and of leadership.

Knowledge is the result of action generated by an individual, who processes information received from reality. Instead of reviewing innumerable attempts to define reality, which has taken the intellectual energy of philosophers of all times, I simply consider reality to be everything, that is, natural and supernatural phenomena and facts, physiological and sensorial, emotional and psychic reactions and social interaction, indeed everything, which is permanently changing.

The species *homo* is new in the evolution of life. Human behavior is the response to pulsions of survival and of transcendence. In the course of its evolution, the species developed systems of knowledge, in the broad sense of responses to needs and will, taking into account the practical and mythical motivations. Different systems of knowledge were developed, with the same aims, in response to different natural environments. These systems include, invariantly, strategies of observing, of comparing, of classifying, of evaluating, of quantifying and measuring, of representing and inferring and of communicating. These strategies give origin to languages, myths and religions and to a set of values which regulate behavior. The complex of strategies and their consequences constitute a culture. This is one of countless concepts of culture, which works for this narrative. As we can easily infer from the elaboration of my concept of culture, the strategies are contextualized in the natural, social and mythological environment. There may occur similar strategies in different environments, but it is undeniable the contextual essence of a culture.

My main interest is to understand the origins and the evolution of the strategies leading to a culture. A method to do this is to look for the evolution of the full cycle of generation, of intellectual and social organization and of transmission and diffusion of knowledge in that context. Of course, this cycle changes, as a result of the internal evolution of the practices and theories grouped as languages, myths, religions and the set of values. They are not static. But there is, clearly, an encounter of different cultures, motivated by several factors, such as territorial disputes and acquisition of natural resources, search for mating partners, mythical motivation, commercial exchanges, wars of conquest and other reasons. There is in the mutual exposition of the encounter of cultures, a dynamic process of change. One culture influences and is influenced by the other. I call this process the **dynamics of cultural encounters**.

The dynamics of the encounter of cultures may result in various degrees of assimilation, of subordination and even of suppression of one of them. What occurs, in most cases, is a syncretism, giving origin to new systems of knowledge. Every encounter reveals ideological problems and conflicts, and it is impossible to remove completely the traces of the assimilated or the suppressed system. Extant traces of the original cultures in the encounters are always present. Ways of doing and of knowing always reveal subtle peculiarities and to identify them is a great challenge to researchers. Culture is a complex of many factors, with an intrinsic fuzziness.

The Program Ethnomathematics

The Program Ethnomathematics is a transdisciplinarian and transcultural research program on the evolution of behavior and knowledge in the human species. It benefits from results and methodological research in paleoanthropology, anthropology and neurocognition, mythology, history and sociology (communitarian life, politics, economics, education and cultural studies in general). The central question is how the human species developed in their evolution in the most diverse natural and socio-cultural environments, strategies to cope with the ample environment. To face this challenge, research must be transcultural and transdisciplinarian and must borrow results and methodology of different fields. It is basic for the Program Ethnomathematics to explain and understand the strategies developed by the human species to deal with reality in its broadest sense. The ensemble of these strategies is a complex system of knowledge and behavior, focused in the satisfaction of the pulsions of survival and transcendence, characteristic of the human species.

This research addresses the emergence and evolution of behavior and knowledge since hominization through *homo sapiens sapiens*. As proposed by Jean Piaget, Lev Vigotsky and many other researchers of human and animal behavior, this research is greatly aided and received hints and ideas, thanks to the observation and analysis of the behavior and knowledge construction of children and adults, from birth to death. Particularly relevant to this line of research is the project of Alison Gopnik to study the evolution of observation and of their interpretations from birth to five year (Gopnik, 2009). We can have insights about the evolution of the species in analyzing the evolution of each individual human being and of their social interactions.

The Program Ethnomathematics initially contemplated the History and Philosophy of Mathematics and its pedagogical implications (D'Ambrosio, 1992). Soon it became clear that it is impossible to discuss History, Philosophy and pedagogy of Mathematics isolated from other disciplines and from other forms of knowledge, in general. It soon opened the way for discussing STEAM in an integrated way. All the five categories—Science, Technology, Engineering, Arts and Mathematics—are self-organizing systems mutually influencing each other. We have to look into them as manifestations of behavior and knowledge, with a holistic, transcultural and transdiscipinarian approach. Behavior and knowledge are dynamic self-organizing complex systems.

Although I have written extensively about this, it is important to clarify that the word ethnomathematics is the result of an etymological exercise. I was looking for a simpler sentence to express "the ways, the arts and the techniques developed by the humans in specific natural and socio-cultural environments to understand, to explain, to deal with daily needs and to satisfy will" when, browsing into etymological dictionaries, I found three Greek roots that approximately express what I was looking for:

techné (or ***tics***) means the ways, arts and techniques developed by the humans;

ethno means specific natural and socio-cultural environments;

mathema means to understand, to explain and to deal with daily needs and will.

Thus I composed the short phrase "***tics*** of ***mathema*** in distinct ***ethnos***" to express "the ways, the arts and the techniques developed by the humans in specific natural and socio-cultural environments to understand, to explain, to deal with daily needs and to satisfy will". Clearly, this led to an even simpler expression, the composed word *tics* + *mathema* + *ethno*. Next step was obvious—the word ethnomathematics. Although this same word had been used before, mainly by ethnographers, the way I conceived it, as a shortening of the sentence "the ways, the arts and the techniques developed by the humans in specific natural and socio-cultural environments to understand, to explain, to deal with daily needs and to satisfy will", is original.

This calls for a warning: do not use ethnomathematics in the sense of ethno + mathematics and even less as ethnic-mathematics, as it is used by ethnographers, anthropologists and even Mathematics educators concerned with cultural issues. Ethnomathematics, the way I use it, is not an extension of the word Mathematics, which is simply the study of quantities, forms and figures and the relations among them. As I explained above, ethnomathematics is a neologism I introduced to express the ways, the arts and the techniques developed by the humans in specific natural and socio-cultural environments to understand, to explain, to deal with daily needs and to satisfy will.

Concluding Remarks

A considerable literature and ethnographic record of different cultural environments illustrate how mathematical ideas are closely related to Art production. Particularly, the history of Art can be interpreted in parallel with the history of Mathematics. Many examples were given at the First International Congress of Ethnomathematics, in Granada, Spain, 1998 and in the subsequent International Congresses of Ethnomathematics.[2]

In my opening plenary address to the Fifth International Congress of Mathematics Education, in Adelaide, Australia, in 1984, which was decisive in establishing Ethnomathematics as a research field, I gave much emphasis to Art as a fertile ground for Mathematics. Some of the illustrations presented in Adelaide are still very relevant. They invite reflections of the arts and crafts in different cultural environments.

Ethnographic research is necessary, since it provides the ground for building the necessary theoretical framework for Ethnomathematics. It is necessary to learn about

[2]To access information and publications on Ethnomathematics visit http://isgem.rpi.edu the site of the ISGEm: *International Study Group on Ethnomathematics*.

the specific ways, patterns, styles and strategies were developed by different cultures to cope with the respective ethno, which is essentially the natural and social–cultural environment. But the results of ethnographic research must be accompanied by critical reflections, not simply showing interesting pictures and practices, reducing cultural issues to folkloric presentations. The ethnographic results must be inserted in a broad social, economical and political context.

The research resort to ethnography implies the recuperation of knowledge and behavior of learned circles, institutionalized in different forms, as guilds, including academies, and also of popular circles in general, non-institutionalized, the so-called *invisible society*. To listen to the invisible society is fundamental for political awareness and commitment, which is a major goal of Education. It is important to learn, how, both institutionalized circles and the invisible society, organize their various forms of behavior, such as moral codes, dressing, speech and of knowledge, which includes **Science, Technology, Engineering**, folklore and the **Arts** and **Mathematics**.

My proposal for STEAM Education includes critically learning and discussing the criteria of credibility and of group acceptance, such as "this is correct", "this is legal", "this is despicable", "this is ethical" and so many forms of acceptance and rejection. In the case of the Sciences, the criteria are of epistemological and methodological, as agreed by peers.

It is particularly important to transmit mathematical knowledge, necessary for life in modern societies, but it can not disregard the multicultural reading of mathematical knowledge produced by the people. Equally important are analyses of artistic production, which give precious insight into the economic and political texture of societies and thus provide the framework that will back the political dimension of teaching Mathematics in schools. Both Mathematics and Art go together as complementary strategies to cope with the reality and its representations in a given natural and socio-cultural environment.

This is the way I consider the **Program Ethnomathematics** a major theoretical support for **STEAM Education**.

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Chapter 12
Reflections on STEAM in Education

Victor N. Kobayashi

Abstract The introduction of the Arts in STEM education is welcomed as it provides the opportunity to integrate the preoccupations of scientists, technologists, engineers and mathematicians. The emphasis on my reflections is not an effort to make a case for the inclusion of "art education". My task is to sketch briefly how an understanding of art itself as an aesthetic pursuit provides the opportunity to reveal the fact that the aesthetic response has been basic to driving not only the practice of STEM endeavors, it also helps persons of all ages to regard life itself as education, and provides a guideline for youth to find a place in the world of work, that is not only fulfilling to the self, as well as a life-affirming global society that includes those who support a society dependent on advances in science and technology. Current developments in science, made possible through new technologies, increasingly make us aware of how complex human learning is, yet the holistic integration, that is the aesthetic response, indicates an awareness to the possibility of being a part of a global society in these turbulent times.

> The study of our psychology becomes more sophisticated through our understanding of the biochemistry of the brain. The study of theoretical physics is nourished by the passions and emotions that animate our lives. (Carlo Rovelli, p. 75).

The A in STEM for Art

Placing an "A" in STEM provides an opportunity to change our interpretation of education, formal, informal, and nonformal, by blurring the differences between STEM areas through an emphasis on Art, while also acknowledging the important fact that STEM areas indeed have had a strong impact, for good and for bad, on the state of the world to this day.

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Rather than treat Art, as a separate subject matter or disciplinary area, I instead argue that when Mathematics is regarded as "Art" as a creative, endeavour, that provides opportunities to perceive and construct patterns that assist in understanding ourselves as well as the complex universe we are born into: the "A" for Art in STEAM is transformed into "A" for aesthetics as the basic Art of being alive and awake in the world, which is the basic aim of education, and goes beyond the pedagogy driven by assessment through STEM testing. Similarly, I make the case for the areas of Science, engineering and technology, perhaps less "pure" than mathematics when it comes to a preoccupation with that which is a plaything of the mind, which elicits joy in life.

Mathematics as Art

Towards the end of a distinguished career at both Cambridge and Oxford Universities, in 1940, G. H. Hardy, (1877–1947) published *A Mathematician's Apology*, a book that has been read more widely than his brilliant treatises on abstract number theory that were read by the small but erudite world of professional mathematicians specializing in number theory. *A Mathematician's Apology* book went through many editions and is still in print, including a post humous edition in 1967, with a forward by Hardy's friend and colleague, C. P. Snow, whose *Two Cultures* revealed the chasm between the science community and the humanities/Arts communities in education and society, a gap that continues to this day, while also pertinent to STEAM and education.[1]

> "A mathematician, like a painter or a poet, is a maker of patterns," wrote Hardy (1990, p. 84). Mathematics is "frozen music," an art form like J. S. Bach's playful use of counterpoint and rhythm in his fugues, that had order, complexity, and harmony, yet at the same time elegantly simple; but music was an artform that took place in time, while mathematics as art was "frozen" in time. Both could be "pure" free of any direct reference to the outside world, but internally meaningful to the mind.

Hardy was one of the pioneers in using the term "pure mathematics," that is to say, a mathematics that was not at all concerned about its applications to solving a community's problems. He was an important spokesman for the idea that mathematics in its purest form was primarily an endeavour that was done for its own sake, like Art for Art's sake, rather than one undertaken for its practical applications to the "real" world. Earlier, in 1908, he published an influential and pioneering textbook for undergraduates *A Course of Pure Mathematics* that freed mathematics teachers who delighted in creating abstract patterns and forms in the mind, through imagination, transcending the mundane workaday world of things, by creating its own reality, like that of the [pure] artist, and thus enlivens existence. Hardy provided the case for the important place of aesthetics, of being alive, by having the fortune to have the talent to be a maker of patterns in mathematics as a form of Art:

[1]The original edition is in public domain in Canada and published electronically by the University of Alberta Mathematical Society, March 2005. http://www.ualberta.ca/mss/.

> A mathematician's patterns, like those of the painter's or the poet's must be beautiful, the ideas, like the colors or the words, must fit together in a harmonious way. There is no permanent place in the world for ugly mathematics. (Hardy, 1940)

Extending and Blending Mathematics, Music and Science as Art Forms

Hardy's idea of time disappearing in mathematics vanishes when mathematics as Art emerges as a performance Art: mathematicians madly scribble on the chalkboard to an audience of other mathematicians, come to a magnificent coda, in the form of the solution to a mathematical proposition, followed at times by applause from the spectators who follow the thinking that is expressed on the chalkboard. The performance is also enhanced when the body language of the performer fits the pace and tempo, of the performance, such that the performance is akin to dance, to choreography. The performance itself becomes a work of Art, an integration of mathematics–music–dance.

I have also seen this occur in schools, where a student may volunteer to solve a problem in algebra at the chalkboard for their teacher and fellow classmates, who had also been assigned the problem as homework. The intensity of the performance can sometimes be electrifying such that we break out into a spontaneous cheer at the sheer artistry of the performance, suggesting that the students and the teacher (myself in this case) have been successful in working as a team, rather than as rivals. Imagine an awkward teenager suddenly becoming eloquent and graceful before the class, as he demonstrated a proof originally assigned as homework. Classic mathematical proofs such as those of Euclid and Pythagoras are seen as scripts, from which the student and teacher breathe new life into the classic through reproduction of the proof, much like actors and musicians, enliven the story and score by acting it out in a graceful yet intense way.

The lateral shift from Euclidean to algebraic geometry, attributed to Renee Descartes, is also a high point in the history of mathematics as Art. The thrill of this invention, when grasped by students, provides again memorable aesthetic experiences that show the inventiveness and creativity involved.

Something similar happens when we recall the legend of the Greek mathematician-scientist-engineer-inventor Archimedes as he solved the technological problem of estimating the volume of a human body while sitting in the bathtub that overflowed. The volume of water displaced was directly proportional to the volume of the position of his body in the water. His "aha!" moment was so intense that he ran into the streets of Syracuse, dripping wet and completely naked, exclaiming "Eureka!".

Music and Astrophysics

The physicist Alexander (2016) describes how the vibrations of music, felt in his body and mind, like a jazz musician resonates and harmonizes with the complex vibrations that his professional work in the abstract world of theoretical physics as a description of the universe. He acts out the vibrations in his discussions while expounding on the energy waves in the unseen universe of astrophysics. Music conveys the felt complexity and beauty of mathematical pattern that are also transductive reproductions of abstruse ideas which students may respond to intellectually. Alexander's experience of the interconnections between complex music and theoretical physics were inspired by African American jazz giants like John Coltrane and Yusef Lateef who had been fascinated by connections between seemingly unrelated material like mandalas, music from non-Western sources, including music as analogues, an approach that is studied in the idea of isomorphism (literally having the same form) in mathematics, for example. There were counterpoints in the breakthroughs in theoretical physics like with musical forms, some very complex, and some from other cultures that Lateef, especially, incorporated into his work. His approach in teaching helped his students understand and appreciate the complexity of patterns involved in studying astrophysics, and it had its counterpoint in music that harmonized felt patterns with that recognized by the intellect.

Abduction

The examples above can be viewed as what C. S. Pierce called "abduction" as referring to the leap in thinking ("intuition") when two sets of seemingly unrelated data derived from observation are brought into relationships through generalizations that bring seemingly disparate data into some kind of order or pattern that may be expressed in a mathematical language.

An example of a successful abduction in chemistry is Dmitri Mendeleev's invention of the periodic table published in 1869. When I first encountered the table in high school chemistry in 1949, I was struck by the patterns that Mendeleev discovered when he listed elements in ascending order, by their atomic number (proton count) beginning with the lowest, hydrogen as 1, in rows, and found that those with higher numbers similar in key chemical properties formed columns when placed under the lower numbered elements that had similar key chemical properties. There was thus an ordering, a pattern, such that elements that formed a column under fluorine (the lowest atomic number of the group) were, including Fl itself, chlorine, bromine, iodine, they had properties in common and were named "halogens," which means "salt producing," in that they are toxic to living organisms in elemental form, but when bonded with metals (such as sodium), forms a salt, sodium chloride, which is common table salt. The term "halogen" means "salt producing". The "alkali" such as sodium and potassium form a column under lithium the alkali element with the lowest atomic number of 3.[2]

Over the years, Mendeleev's original table has been greatly modified, but it provided a radically important framework or "paradigm" for further exploration in the field of matter at the atomic level, and their properties, with the discovery of isotopes, with neutrons that added to the atomic weight, without changing the atomic number of a particular element, and further addition to the "content" of the element. Although Mendeleev was a chemist, his table showed interrelations between chemistry and physics, a commonplace occurrence today in the cutting edges of Sciences, mathematics and Art that indicate the difficulties in making decisions in schooling for children based on their assessed interests, and the more specialized courses in all fields that ultimately intersect in the life of each individual.

Mendeleev's table had missing elements that opened the possibility that they may nevertheless still exist in nature and has undergone many modifications, including the expansion of number of columns. Marie Curie (1867–1934) discovered two new elements, radium and polonium (named for her native country), that were radioactive, with higher atomic numbers than those that Mendeleev listed, and these were then included in the table, while also setting the groundwork for artificially producing new elements (that were not known to exist in nature at that time) that were highly radioactive and also extremely unstable in that they decayed rapidly into less heavy molecules. She also coined the term "radioactive" for highly unstable elements and died of an illness related to the fact that she carried vials of radioactive material in her pocket between various tasks and thus was like a martyr in helping enlarge the Science of medicine, and thus biology. She earned two Nobel prizes in Science (one with her husband) and helped to dispel the expectation that women could not excel in Science. It also points to the unification of physics and chemistry in Science and set a major foundation in the engineering of nuclear weapons.

Mathematical Abduction

An example of abduction in mathematics is Euclid's proof that the number of prime numbers has no limits, i.e. infinite. Because a prime number is defined as a natural number that cannot be reduced to factors other than itself, it would exclude zero and negative numbers. Euclid simply listed all the prime numbers, in ascending order beginning with 2, and continuing with 3, 5, thus, 2, 3, 5, 7, …, P with P as the hypothetical largest prime number. Euclid then considered each of the prime numbers, beginning with 2, and 3, as factors such that the product of all of the prime numbers would generate a new prime number if 1 was added to the product, and thus

[2]The first element, hydrogen, lies at the highest column, but is not considered an "alkali." For reasons of brevity, exceptions and their basis are not included in my discussion, which may rise questions from those who are familiar with the periodic table, some of which I am not prepared to answer.

proving that there was no final prime number in the sequence, and that the number of prime numbers was infinite. This type of proof of negating the hypothesis (that the number of primes is finite) has been called "reductio absurdum" by mathematicians. Hardy uses Euclid's proof as an example of how mathematics is an art form that deals with ideas composed of deeper abstractions.

Intuition and Its Aesthetics

These connections often come in a flash of insight, which is analogous to the aesthetic experience that comes to an artist completing a work of Art which others in turn may experience. There is a sense of integration of experiences of elements that might otherwise appear unrelated.

> Scientific reasoning is often regarded as an interplay between (1) facts gained from observations, measurements that provide empirical evidence (induction) and (2) generalizations, that organize the facts so they can be verified and modified through further observations, that may include experimentation, such as in a laboratory setting, or confirmation by observation such as when one of Einstein´s major theories is validated by such phenomena as the curvature of stellar light as it passes fields of intense gravity of other celestial bodies in cosmic space. In Mathematics as a Science, the abductive process lies in a proposition that links statements through a series of ordered deductions, which constitute proof of the validity (or nonvalidity) of the proposition, that is the hypothesis.

One of the significant figures in Hardy's work as a mathematician was Srinivasa Ramanujan, a young clerk of Tamil Brahmin background in British India (today Tamil Nadu state that includes the capital city, Chennai, formerly Madras). Ramanujan had little formal education, but spent much of his time working out Mathematic equations many of Hardy's invitations to Cambridge with the support of his close colleague in Mathematics, John Littlewood to work with him when he was further impressed with Ramanujan's uncanny ability to recognize prime numbers for numbers not ordinarily known to be prime. When tested, the Ramanujan was almost always accurate in his intuitions.

Ramanujan also arrived at solutions to difficult mathematical equations intuitively, but Hardy insisted that it was necessary for Ramanujan to show proofs of the validity. Ramanujan could not understand, as he had already provided the solution. With great reluctance, combined with the difficulties of adjusting to English society, and contracting tuberculosis, Ramanujan undertook the laborious task of providing the proofs, such that the Royal Society of Mathematics welcomed Ramanujan as a fellow in mathematics at Trinity College, Cambridge. Ramanujan returned to India, rejoining his wife, and died in 1920 at age 32.

Aesthetic Experience, and Science

Ramanujan is an example of what mathematicians call “intuitionist” approach as compared to “formalists” who require proofs to validate what might have been inspired intuitionally or is discovered through proving a theorem, such as in Euclidean geometry, for example, Descartes is important as a formalist who transformed geometry into algebraic expression, thus making it possible to have a formal proof in terms of equations that prove that linear algebra is isomorphic to the geometry of a straight line. Often, leaps of intuition initially form the theorem or hypothesis that would be proven true or false, or modified, in some sort of approach that does not always start with the hypothesis or theorem which is important in the teaching of Science or mathematics. The performing art approach to mathematics may not necessarily convey formal understanding of mathematics, but does convey a delight in the performance, including the admiration of the versatility of the teacher, and some understanding of the joys of being immersed in an otherwise coldly abstract and often mysterious subject.

Abduction and Education

Today the proof seems “obvious” and even trivial to teachers who ca not think historically about past states of mind, but it need not be so for the naive student who may experience an insight when following Euclid’s argument. In fact, it is often important to prove or disprove the “obvious” since the “obvious” has been derived from past abductions by human minds.

This simple and elegant proof may become so obvious that it may seem trivial to teachers who teach mathematics in the lower levels even if the idea of infinitude is an important concept in advanced mathematics. Children who have not yet learned how to count may not also understand that the word “number” may come to have at least two meanings that include its meaning as a symbol and sign (e.g. as a numeral) and also as a quantity. When the word “number” is used as a descriptor of numbers themselves (e.g. number of prime numbers), it changes the meaning of the word “number” used in the phrase that has an analogue in the seeming contradiction, often stated in Japanese:

> There are many *Fuji* mountains in Japan, but only one Fuji

The idea here is that the word “fuji” stands for all mountains that have the form (i.e. pattern) of the iconic Mount Fuji, but Fuji is the most significant, because it is also the tallest and most beautiful mountain in Japan that can be seen from a great distance. Its appearance seems to be in a perpetual state of change, based on the sun’s light, clouds, haze, change of seasons, yet there is also something eternal in the idea of Mt. Fuji. The analogues are unlimited as mounds of sand piled in a Zen garden are constructed like fuji—they are potentially infinite in number—but there exists only one Mt. Fuji, a source of Bertrand Russell's existential element that reduced Aristotle's idea of logical reasoning as one that distinguishes sets or classes, from the fact that members of a class are existential, are individuals, and do not compose a subset. A set without members, still remains, an empty set, an imagined abstraction that remains in our mind. Sets and subsets are abstractions, while members are individual minds, an insight that is suggested in Kant's categorical imperative.

"Number" itself is a pattern, and the ordering of numerals itself forms a pattern.

It comes in the form of an insight, an "intuition. An experience" that is subjectively felt in both the speaker and in the listener (or reader) when both "dig it" or get into the same "wavelength". Insights such as these are important in learning, as it is a form of abduction as Pierce defined it.

This suggests to me that important learning takes place from the earliest years of infancy, and that it occurs as "steps" in a learning curve, suggesting that the word "learning" itself is complex, since each step makes "learning" comes in *discrete* steps, rather than in a smooth continuous curve. The learning curve also involves "meta learning", thus making the micro-elements in the line of the curve look more like a series of "steps" rather than at the micro-level (of the individual), as compared to the macro-level (large populations), an idea that has major implications as to how we "measure" the process of education.[3] The *number* of intuitions in an individual learned at age 15 is uncountable, not even perceptible, not to mention the fact that only philosophers reflect on what the aesthetic experience "means".

Even if "zero" is a concept, children may have a subliminal glimpse of the *idea* of zero: in Japan, for example, children learn to count with their fingers by opening a closed fist, while looking at the objects to be counted. Americans look at the objects to be counted by pointing to each of the items and saying "one, two, three" (or later perhaps by "chunking" by counting doubles, triples, etc. By traditional Japanese etiquette, it is considered somewhat impolite to point at persons when counting, and thus opening the hand to count, is preferred over counting others in a face to face group. When a person points to each person, when counting, it seems to be treating a person as a thing, rather than as a person, since the matching of number to fingers and to the number of persons in the room is made more subjective, is more *mentally* imagined, and *in* (rather than outside of) the person's mind. "Zero" is an analogue to "no mind" which is "an empty mind" that is also full of potential, rather than the usual conception of mind as "tabula rasa" in the history of Western education and its relationship to epistemology. "Emptiness" implies in this type of thinking as having multiple possibilities, and thus the opportunity to break out, i.e. be freer to act and have abductive insights.

The connection between numbers and fingers is still one-to-one, but the state of the hand itself is taken unconsciously into account, such that "zero" is suggested but not named, while the open hand also indicates "five" along with the remainder of

[3]Gregory Bateson is the one who explored this and many other ideas with others, including himself, and whose ideas on learning is suggested by the title of his important book *Steps to the Ecology of Mind* (1979).

the fingers. “Zero” is an Arabic numeral invented by Hindus in India and adopted by Arabs to become almost indispensable in basic numeracy today. It is a number that seems “obvious” but in historical terms had not been invented as a sign. Pierce interestingly enough was also a pioneer in the science called “semiotics”.

Even the idea of a “natural number” used at times by teachers is misleading, as are “natural” labels on food items that use “natural” to attract consumers to a person who knows and *understands* more Science and mathematics.

The act of counting is a cultural invention that is important in the development of mathematical thinking in early childhood. Warren McCullosh (1970, p. 7) pointed out that the numbers 1 through 6 are “perceptibles” in that human beings and other animals can perceive one-ness, two-ness, up to six-ness, but not seven-ness. Observations of birds and mammals have confirmed this: for example, when a single egg was removed from a bird’s nest, the bird would behave in a distressed fashion, and this would be true only of a nest up to six eggs. However, when there were more eggs than six, and one egg was removed, the bird would not notice that an egg was missing. McCulloch used the term “natural” to mean the more limited group were called “perceptibles” since they could be perceived also by mammals, including human beings.

Thus even the use of the term “natural number” with children may miseducate when they also include the first few numbers that McCulloch called “perceptibles” rather than “natural”. For the act of counting was an invention that occurred in the early cultural evolution of human beings. It is also very interesting to note that the numeral “zero” had to be invented, and thus is sometimes considered not a “natural number” even if we can recognize absence. Indeed “absolute zero” cannot be measured, and thus cannot be observed in science—it is an imagined inference that is scientifically acceptable even by engineers.

Formal mathematics also uses numerals that express both quantity and order that may denote rank that may add to confusion if introduced too early to many children, even though they may, again subliminally, understand how words change their meaning in terms of context. Counting provides ordinals as well as cardinals in one act, such as the 17th in rank is the last person in a group to be counted, makes 17 the number of persons in the group.

Moreover, many children learn to distinguish both types of numbers (ordinal and cardinals) when they learn certain games, for example, within specific contexts, such as in card games. The ability to distinguish and change between contexts is learning “mathematics” as well as important for “actors” and indeed in everyday interactive rituals. The polysemous aspect of prose is learned, and we sometimes disregard such skills in formal education. Poetry also is in many ways a different universe of meanings, compared to “prose”. But “prose” can also be poetic when artfully written, and poetry can be banal and prosaic, when taken too “literally”: aesthetics again in the everyday classroom.

There are exceptional cases whereby such fluidity can be learned when one learns both the meaning of the numbers on a clock face that has numerals that give the time of the day and its relationship to other numbers important in understanding telling time, and a sense of when lunch will be held, especially when the numbers on the clock may have similar but important differences in meaning, as, for example, the difference between 2 in the morning and 2 in the afternoon, which to an adult may seem "obvious". There is relatively more complexity involved in understanding the time of the day in children, and it is always amazing to me when some children quickly learn the differences, even if they have never looked at a clock, for example, at 2 am. Many adults have difficulty converting time depending on the time zone they are when they travel or make phone calls. I have received phone calls at 2 am even by persons who are in my field of study, Comparative and International Education. America had difficulty when educational policy shifted to "metrification," a move to make its citizens to adapt to measurement to the International Bureau of Measurements that is based on standards preferred by scientists, technologists and engineers.

Mathematics, Art and Life

C. P. Snow's introduction to *A Mathematician's Apology* noted the undertones of sadness in an otherwise celebration of mathematics as an aesthetic enterprise. Hardy wrote an elegy to the mathematical energies that waned in his senior years before his death.

Hardy separated "pure" mathematics also from the applied Sciences that dealt with the living world, and which had practical uses, that have come to be viewed as improving society and progressively making the world a better place to live; but Hardy, who lived through World War I, was aghast at the use of science and mathematics that made a small portion of the population wealthier, while others poorer, and moreover destroyed masses of people, using lethal gases and bombing with scientifically constructed propaganda to drive millions of people to support war, all made possible through Science and technology.

Hardy suggests that the ugliness had to do with the social consequences when mathematics was used in the Sciences and engineering—for war and killing were life-negating, thus ugly, the ultimate denial of the aesthetic possibilities of human endeavours. Hardy's anti-war stance was also taken by his colleague, Bertrand Russell, also a top rate mathematician and logician, who devoted much of his later life as a major figure in anti-war movements, and both lived through the Second World War, with mass firebombing and rockets, and nuclear bombs and the invention of the idea of genocide. "There is no permanent place in the world for ugly mathematics" (Hardy, 1940). The same could be said for STEAM.

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Chapter 13 The Synchronicity of Art and Mathematics

Gregory Johnson

Abstract This chapter is a discussion of the premise that there is a correlation between art and mathematics from an instructional as well as a practical aspect. The premise is supported by analysis of the mathematical framework of visual art and review of historical and contemporary empirical research into the linkage of disciplines. The chapter contains historical evidence and discussion of cultural bias as well as anecdotal observation of the author's artwork. The conclusion is that art can be used as a tool in understanding quadratics, abstract principles, and the relationship of geometry to real-world potentialities. STEAM is a modern designation of the developing human educational models understanding its natural cultural significance through art can make it more accessible. Recognizing the legitimacy of art in an interdisciplinary setting is important in establishing an egalitarian connection to STEAM learning. Art is a means to making this connection and demystifying mathematics as separate from the mundane or as a product of the elite.

In order to increase educational opportunities for all people, it is necessary to be creative in approaches to methodology. Understanding the interconnectivity of educational disciplines such as art and mathematics facilitates the dissemination of and access to information by rectifying and developing new pathways to learning. This expansion of educational opportunity is a right we all share as human beings. Like all phenomena in the real world, art is a mathematically based framework. This chapter is a discussion of the premise that there is a correlation between art, mathematics, and science from an instructional and practical aspect. This premise is supported by analysis of the mathematical framework of visual art and empirical research into cross-disciplinary linkages. This chapter contains historical evidence and a discussion of cultural bias, as well as anecdotal observations. The conclusion is that art can be used as a tool for understanding quadratics, abstract principles, and the application of geometry for real-world potentialities.

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To understand the history of human social evolution is to recognize its expression through art. The earliest form of communication was visual: in hieroglyphs, cave drawings, and cuneiform marks on tablets. These early forms of communication were imbued with a common thread, the basic structure we call mathematics. Mathematics is the quantification of the representational in the real world of expression. To take this a step further, just as culture or regionally specific language indicates social structure, relationships in mathematics represent a natural social evolution. The patterns in cloth, decorative designs in architecture, the perspective and dimensionality of sculpture and masks are mathematical equations that can unlock pathways to a certain type of visual literacy. There is also a correlation between the scientific method and the step by step, trial and error process of the creative epistemology in art. Mathematics and the scientific method are basic to the fundamental framework of the artistic canon.

The science, technology, engineering, and mathematics (STEM) acronym is a modern designation for developing educational models to understanding the relevant cultural sources, which can make it more accessible to every society. Recognizing the legitimacy of each culture's history and social dynamics is important in establishing an egalitarian connection to STEM learning. Art is a logical means for making a connection between mathematical and scientific models by presenting a cross-disciplinary perspective, not a divided educational model or a product of the elite.

Art and Philosophy

> Every phenomenon can be experienced in two ways, the two ways are not arbitrary, but are bound up with the phenomenon developing out of its nature and characteristics, either externally or internally (Kandinsky 1928).

Everything we do in reality involves description of our environment. The disciplines of science, mathematics, and art are descriptive by nature. They come into being as an understanding of how we function in the world. Since they are related at their roots, they can be directed towards each other. The number 2 without a related object is irrelevant. Mathematics exists as a way to describe quantity and relationships between objects. In ancient cultures, mathematics extended to represent certain constants in the natural order, to measure the environment, and was equivalent to magic. Science is phenomenal; it describes functions in the universal context through descriptive laws and theories (continually evolving). All cultures in the world possessed scientific knowledge, although currently Western science dominates the conversation, pre-colonial science existed in all cultures worldwide.

Art is the creative process, an actualization of the inner working or raw material of critical thinking expressed visually. In fact, all these disciplines (art, mathematics, and science) relate to the visual and involve critical thinking. The basis for much of the three disciplines is similar and related, each employing aspects of the other. Technology and engineering, the other parts of STEAM, are both products of them and employ them.

Description of Relationship of Art and Mathematics

Mathematics, fundamentally, exists as a marker for real-world phenomena. It underlies everything we do. It is descriptive of most human activity and occurs naturally throughout all societies and cultures. Our earliest understanding of the environment was mathematical. Further, it can be implied that mathematics is a personal and cultural phenomenon. I recently viewed a film "Embracing the serpent" about people of the amazon, on their buildings was a decorative pattern consisting of a motif of repeating dots: an equation represented as visual design. A cultural mathematical symbol has mystical significance. Patterning is the logical crossover between mathematics and art. Mathematics describes how we are in the world, but it only functions in coordination with other mediums. Equations and mathematical theorems are related to something, much as length times width references area, or $y = mx + b$ references a straight line, these are visual concepts.

Artwork comes from understanding spatial relationships, no matter what form, whether in free space or confined to a plane. Art is reliant to an innate understanding of mathematics. Often this expression can be analysed and quantified. Some artists use mathematics purposefully an example would be Josef Albers and his studies using square forms or Barnette Newman and his use of the straight line and the rectangle. Other artists employ mathematics as a means of identifying patterns and look for structures within their work.

The artist starts with a concept and creates the environment to explore this concept. Whether it involves mixing various colours, glazing, staining, or creating screens (chemistry), layering, texturing, sculpting, or printing (construction), or the process of recognizing and repeating effects (empirical research). Art is also reflective of the scientific method as seen in the trial and error approach to discovery.

Visualized Imagination as Mathematics

As stated previously, I relate science, mathematics, and art as interrelated disciplines in the realm of visual imagination. An important theorist in the philosophical and scientific basis for art was the Russian Avant Garde painter Wassily Kandinsky. Kandinsky posited the relationship between colour and geometric shapes; he also justified the links between planar geometry and energy. These principles were applied to his abstractions "The work of art mirrors itself upon the surface of our consciousness; however, its image extends beyond, when the sensation has subsided. A certain transparent partition, abolishing direct contact. Here too exists the possibility of entering arts message, to participate actively, and to experience its pulsating life with all ones senses" (Kandinsky, 1947).

His first task was to scientifically analyse from a historical perspective his theory. He referred to his work in terms of pure science and utilitarian science, the former being theoretical and the latter applied. His research into scientific analysis of the picture plane took three steps:

1. Investigation of each element in isolation;
2. The reciprocal effect of elements in combination;
3. Conclusions drawn from the analysis of the first two steps.

Kandinsky treated mathematics as a living thing; he referred to the geometric point as "the ultimate and most singular union of silence and speech" (Kandinsky, 1947). His further research involved understanding the relationships between objects placed on the plane (circles, triangles, diagonal lines, random marks). What resulted was a series of theoretical assertions regarding the creation of visual energy, balance, and harmony in his artwork. He also researched the relationship of colour to geometry and adapted his ideas into a philosophy of creating paintings.

Another artist working in the Bauhaus school during the pre-war years (1921–1931) was Paul Klee. Like Kandinsky, Klee used mathematics and scientific principles to teach his art students. His major work on the subject was contained in his *Pedagogical Notebook*. In his introduction to the notebook, Moholy-Nagy the Hungarian photographer states that:

> Man painted and danced long before he learned to write and construct. The senses of form and tone are his primordial heritage. Paul Klee fused both these creative impulses into a new entity. His forms are derived from nature, inspired by observation of shape and cyclic change but their appearance only matters in so far as it symbolizes an inner actuality that receives meaning from its relationship to the cosmos (1953).

Whereas Kandinsky based his work on a philosophical approach to the creative process, Klee used a methodological approach in four sections proportionate line and structure/dimension and balance/gravitational curve/kinetic and chromatic energy, his text ranged from a discussion of the point and line phenomena (similar to Kandinsky) to a step-by-step approach through all manner of possible permutations of mathematics and science. His work encompassed representative planar and structural geometry by discussing modes of energy (passive and active) related to geometric figures concluding with mathematical equations related to form and structure. Klee continued the discussion by relating natural science to abstract geometric ideas. Klee believed that comprehending the natural world was crucial to understanding the creative process. He thought an artist needed to understand anatomical systems such as the circulation of blood and the lever and fulcrum relationship of bones and skeletal muscles, or the working of simple mechanical forms. From this discussion, he proceeded through natural dynamism in balance, action, and symmetry using what could be called elemental physics. In his conclusion, Klee brings all the previous discussions together as a basis for colour theory (balance and symmetry) and construction of images in relation to the pictorial plane.

Ubiratan D'Ambrosio, the Brazilian mathematician, is a philosopher of the mathematical aesthetic. He sees mathematics and science through the filter of culture and transcendent expressive humanity, as exemplified in his statement "[The] human mind is a complex of emotional, intuitive, sensorial, rational perceptions, involving all at the same time. Maybe we have been emphasizing too much the rational perception and denying, rejecting, and repressing the others" (D'Ambrosio, 2011). He discusses the cultural narrative of mathematics in what he calls ethnomathematics. "Ethno mathematics challenges the conventional view that science and this includes mathematics, is a uniquely modern western phenomena, even in the absence of a recognized method" (D'Ambrosio, 2011). An example of this idea that cultural groups have an innate relation to mathematics outside the Western model is seen in precolonial Mali, where there was a system of mathematics that supported architecture. In the Americas, both the Aztec and Mayan cultures developed sophisticated mathematical systems tied to specific cultural function such as astronomy, architecture, or religious practice. Incans of Peru had a knotting system of multi-coloured strings attached to cords called quipu, which employed an arithmetical table and abacus called a *yuupana.* The system was complex and specific containing qualitative and quantitative information of value to the society especially in commercial applications and the historical record. This links with D'Ambrosio's concern:

> I am concerned with the ways, modes, styles, arts, and techniques, generated and organized by different cultural groups for learning, explaining, understanding, doing and coping with their natural, cultural, imaginary environment (D'Ambrosio, 1979).

D'Ambrosio sees mathematics reflected in the artefacts (artwork and design) from different cultures. For instance in ancient Greece, we see a practical mathematics, present in art and architecture, in commerce, in military strategy coexisting with a theoretical mathematics in the Euclidian style. He also sights the value of examining folk tales, artefacts, mythologies, and fictions for mathematical correlatives to culture.

As D'Ambrosio states

> [The] human mind is a complex of emotional, intuitive, sensorial, rational perceptions all at the same time maybe we have been emphasizing too much the rational perception and denying, rejecting and repressing the others. Indeed, there is a general feeling that as a math teacher, one has to teach *serious math*, that is objective reason, and to stimulate rational thinking among the students. Is it possible to build knowledge dissociating the rational from the sensorial, the intuitive and the emotional (D'Ambrosio, 1985).

Sonal Transcription

Descriptive identification also extends to the representation of sound in written language. This form can even be varied visually through calligraphy, which is both aesthetic and indicative of aural Information. Pictorial representation preceded modern language in the form of hieroglyphs and cuneiform as symbols and marks conveying meaning. These languages of antiquity through their abstract organization of symbolic text were descriptive of language represented as a cultural phenomenon. Egyptian glyphs were pictorial storyboards that could be translated from the visual beauty of fictive imagery to their historical and mythological reality.

Musical notation is a representation of sound that uses visual and mathematical aspects of reality to express an abstract aural language. Western musical notation, exemplified in abstract symbols (quarter notes, clef marks, etc.), is a visual representation of sound that denotes mathematical and scientific principles of time, direction, and volume (sonal). Modern digital representation of new musical forms (jazz, blues, electronic) has expanded on the traditional Western historical visually representative notation through expressions such as *Syndal's visualization*, a series of linear groupings that allow for micro-tones and ambient noise. Musical Instrument Digital Interface (MIDI), an electronic music sequencer program, presents musical notation in patterns of squares and rectangles, and pitch and tone (high and low frequency) can be represented as a helix pattern or pitch that can be pictured as a circular wheel of vibration. Joshua Distler (Heim, 2011) represents musical notation as frozen waveforms (digital sound patterns) or musical figures similar to ink blots created by sound.

Art Discussion: Personal History

Art like science is a process of experimentation and discovery. An artist over time refines his craft and within in the framework of his genre makes conclusions that can cross disciplines into compatible areas.

As a child, I had an acute sense of spatial relationships and visual perspective; I could reproduce natural images in great detail. My teachers had me draw maps of countries with geographic details such as mountains, lakes, rivers, and coastlines. I drew parasitic lifecycle diagrams for my father's zoology classes. As I matured, my interest turned to photographically inspired portraiture. I began my higher education in biological science, but turned to art and art history as a major interest. At some point, I realized that what fascinated me was not the image itself (figuration), but the microcosm or supporting structure. Photorealism gave way to organic abstraction. This opened new areas of exploration and creativity, new forms, and experiments in colour theory.

I looked back at my art history studies to understand the dialectical and theoretical nature of Western art and other cultural and art influences outside of Europe.

The Russian artists at the time of the political revolution combined theoretical discussion of social issues as related to the metaphysical and scientific prospective of art. They envisioned the possibility of art combined with science and mathematics to create a counter to the religious and romantic art of Western Europe. The suprematist's sought to place art in the practical world of science, design architecture, and even politics. I found especially interesting Kandinsky's book *Point and Line to Plane* (1928) with its philosophical exploration of the effects of geometry and colour on visual acuity. His discussion of the concept of weight and energy within compositional construction is a valuable tool (Kandinsky, 1928).

I further argue that conceptual ideas in art were universal and culturally dependent. Every culture has an innate style or compositional framework. The Kassena people of Burkina Faso produced for centuries' wall art that can be seen as related to Western-style modern abstract art. The French impressionists borrowed ideas from

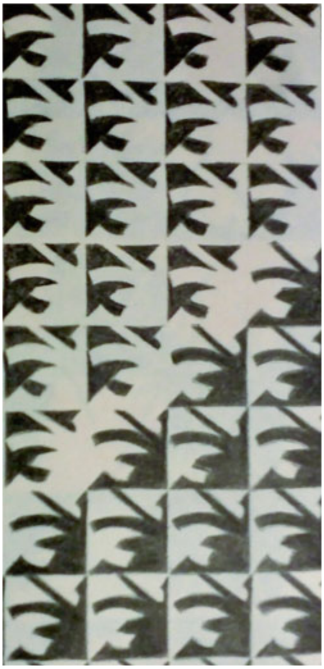

Fig. 1 Tessellation on M. C. Escher

the Japanese printmakers. Picasso and Braque took their inspiration from African sculpture and developed the cubist style. Like scientific discoveries, styles in art were occurring coincidentally all over the world during various eras of political change and expansion.

My earliest study related to mathematics was an exploration of the repetitive patterning undertaken by M C Escher (Figs. 1 and 2). In the years 1938–1942, the Dutch graphic artist Escher developed what he called his "*layman's theory*" on regular division of the plane by congruent shapes. During this time, he also experimented with making repeating patterns utilizing decorated squares employing combinatorial algorithms. Escher was concerned with certain patterns within a set of four squares, which when rotated sequentially produced variations on the original set. Working through combinations of four squares, he created a mathematical system, the number of variations possible in a set pattern. By limiting his patterns (field), he could come up with a formula, which was accurate and predictive. After exhausting the square format, Escher moved on to patterning on triangles and even three-dimensional cubes.

> Escher did investigate some things of the plane triangles and create patterns for describing triangles, but these were not equilateral triangles. The focus of that investigation was not the patterns, but rather the number of different ways in which a triangle could tile the plane in a "regular" way, that is in which every triangle was surrounded in the same way (Davis, 1997).

The idea of limitation of scope as a methodology creates an effective area to make certain conclusions. Escher was interested in probability or the predictive power

Fig. 2 Tessellation on M. C. Escher

of his controlled manipulation of the geometric fields; aesthetics were a secondary effect of his patterning. I improvised on his basic premise, but his method of reflective systematic experimentation was also important. He used the same methodological approach that research scientists or theoretical mathematicians employ. This is a good example of the similarity in approach between disciplines.

My work is intuitive. After I begin to work in a certain way, I analyse and assess what I have done and use what I have learned to progress. At present, I see clearly the relationship between my work and certain mathematical theories. I utilize the Fibonacci numbering sequence (1 + 2 + 3 + 5 + 8, etc.) in either patterns of 1:5 or 1:3 and variations of those patterns, using developed colour theory against the pattern to create a synthesis with another type of geometric patterning similar to pixels, called circle packing. The relationship of the circular form to a geometric plane (triangle/rectangle/square). The Venn diagram is the classic example (Figs. 3, 4, and 5).

My previous work, which I still revisit, is related to fractal geometry as proposed by the mathematician Benoist Mandelbrot (Mandelbrot, 1982). It is the reducing of an image into rough or complex shapes. I experimented first with symmetrical patterning (similar to ink blots) and then broke them down into multiple repetitions of simultaneous structural elements. These earlier works (concentrating on black and white forms without colour) produced images on a plane exhibiting field ground reversal (see Fig. 6).

Fig. 3 Venn diagram improvisation

Some of this research has led me to an interest in natural forms. The intuitive and positive nature of design through evolutionary function as described by Fibonacci sequences can be seen in flora. How could these natural structures be used in design or engineering projects? The premise being that natural forms are perfectly designed for things that will become vital in the future. The conservation of energy, the proper utilization of dwindling resources, the growing threat of climate change, and the natural aesthetic of harmony with the environment.

Concluding Comments

In conclusion, there are historical, theoretical, empirical, and cultural interdisciplinary linkages between the arts, science, and mathematics. I have employed aspects of these disciplines in my artwork. This synchronicity of expression can be explored in an educational context to expand and enhance curriculum Science Technology Engineering Art and Technology (STEAM). Cross-disciplinary activity could also lead to innovation in related fields such as architecture, design, and environmental

Fig. 4 Venn diagram improvisation

Fig. 5 Venn diagram improvisation

Fig. 6 Black and White field Ground

technology. I would also add that an emphasis on art in the cultural context makes mathematic study more relevant in disparate cultural groups.

Cross-disciplinary study of mathematics and science using the filter of art is a creative activity that can bring the emotional and sensorial perspective in line for educational purposes. By using this practice, we may have some influence in expanding interest and increasing the development of all educational models. We can conclude by arguing for a new approach to presenting mathematics to students. There is an internal mathematics that is expressed visually in art and this visual approach can demystify mathematical instruction.

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Chapter 14
The Hidden and Essential Narrative: Language and Visual Art as Learning Tools in STEM

Helen Harrison

Abstract Science and art are often viewed as highly disparate fields. However, just as science explores and questions the nature of life, art offers an equally powerful inquiry into the forces that shape our world and the human experience. Unknown to many, science is inherently creative and rich with narrative and personal connections. The arts have the potential to make the stories, impact and intrinsic beauty of scientific research more visible and approachable for other scientists and the public, especially in areas such as medicine and disability. Using the theoretical framework of "Narrative Medicine" developed by Dr. Rita Charon, MD of Columbia University, this study aims to generate three pieces of visual art as a response to the work of three scientists at the University of California, Berkeley who study the underpinnings of disabling psychiatric and neurological diseases. The aim of this project is to use artistic expression as an educational tool to make the creative and emotional process of science, and an understanding of neurological disabilities, more accessible for people from different backgrounds. Using the three tenets of Narrative Medicine "attention, representation, and affiliation" (Charon 2006) to guide the translation of this research into art, the scientists will be interviewed to explore the premise of their research and their feelings and personal connections toward the implications and goals of their work (attention). Then, they will choose a meaningful image generated during the course of their research that is representative of these qualities, which the artist will translate into a painting that exemplifies scientist's interview responses (representation). The completed paintings will be presented alongside a short summary of the research and scientists' personal connections as a means of increasing the visibility and understanding of these projects, the subjective experiences of the scientists, and the experience of disability for a broader and mostly non-academic audience (affiliation).

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Introduction

Narrative in Science and Medical Research

Science and art are often viewed as occupying entirely separate domains. But, just as science explores and questions the nature of life, art offers an equally powerful inquiry into the forces that shape our world and the human experience. Science and medicine are inherently creative and rich with narrative, and the arts have the potential to make the stories, impact, and intrinsic beauty of scientific research more visible and approachable for other scientists and the public. Looking back through history, we see that these fields have been inextricably linked for hundreds of years. There are also numerous contemporary examples of artists and scientists who use oral, visual, and written narrative to educate, express their thoughts, and relay personal stories that relate to topics and discoveries in science and medicine. These narratives have the potential to call our attention to fascinating research that would otherwise remain hidden to people within and outside of these fields. Yet examples of these narratives often fail to reach public awareness, perhaps because the notion that science is esoteric, difficult and exclusive is reinforced early in primary education up through to sink-or-swim foundational courses in high school and college that end up discouraging many interested students from pursuing a scientific career. Others still may be turned off by the lack of diversity, in both identity and thought, in STEM fields. Many of these students may end up as adults who feel that science is inaccessible and not worth pursuing.

For the most part, the work that STEM fields produce uses an objective style and contains language that feels inaccessible, as exemplified in scientific journals. Seeing information presented almost exclusively in this way has caused many to wrongly interpret these fields as necessitating emotional detachment and limited flexibility in how ideas are presented. The resulting paradigm in both academic and non-academic circles is that science is strictly objective, technical, and concrete, while art is concerned with the emotional, unstructured, and abstract. When these qualities are conceptualized as incompatible, it follows that so too are the fields themselves. However, documenting the world's phenomena through various forms of media and instrumentation in order to comment on the patterns and events that present themselves in our daily lives, and to share those with others to facilitate connection, discovery, and discourse, is a process that both artists and scientists share. Given the compatibility of these two domains, creative writing and the visual and performing arts can and should be employed as a way to learn and reflect upon scientific research and concepts in an engaging and interesting way.

This project is a small-scale demonstration of how oral narrative and visual art might be used as teaching tools to introduce biomedical science and research topics to an interested audience that may not otherwise know about these topics or have the specialized training to learn about them from existing media targeted toward experts in the field. The methods used in this project could be adapted or modified for use in other educational settings, such as a classroom or museum. Presenting STEM topics through the use of written, oral, and visual storytelling has the potential to provide the audience with an inviting alternative way to engage with a new subject, as opposed to a traditional lecture, paper or article which might contain interesting information that is presented in an inaccessible way. The question presented is: Does the humanistic quality of a work of art, a creative writing piece or an interview have the potential to confer more interest and give the reader or viewer a unique way to learn new information (especially if the presentation has a participatory element), inviting audiences into a world they may not otherwise have been able to access?

For this project, three works of art were created in response to interviews I conducted with, and scientific images provided by, three researchers investigating the underlying biological mechanisms of neurological and psychiatric diseases at the University of California, Berkeley. Then, five individuals were presented with the artwork, as well as the original scientific images, and non-technical summaries of the research findings, based on the interviews and current scientific literature. The participants, who all lived in the San Francisco Bay Area but had different personal and educational backgrounds, were asked to compose a written reflection in response to the presentation in the style of their choice. The goal of this project is to pilot presenting scientific art generated from different research projects, in the form of a participatory gallery, as a way to invite individuals from different backgrounds to learn more about neuroscience research studying illnesses that are well known but not well understood by the public at large. The use and understanding of language in any learning domain is a human right, and the inclusion of a participatory element into this method of presenting information gives greater agency to participants so that they may exercise this right when engaging with information about scientific research. The desired outcome of this project would be that participants are able to learn something new and interesting about these disorders, and the research that aims to increase our understanding of them, by forming their own narratives around being presented with this information in a new way.

Research Background and Methodology

The conceptualization of this project was sparked by my studies in Public Health as an undergraduate at UC Berkeley, through which I became interested in serving populations that were differentially affected by psychiatric and neurological disorders. In addition to learning the biological underpinnings and epidemiology of these illnesses, a strong component of my education involved developing an appreciation for the importance of individual narratives as a way to learn about the experience and impact of psychiatric and neurological illnesses on the part of patients, providers, researchers, and society. In particular, my approach was stimulated by an Art Practice course titled "Art, Medicine and Disability" taught by the artist and professor of Art Practice and Disability Studies, Katherine Sherwood. Neurological subjects are ubiquitous throughout Katherine Sherwood's paintings, inspired by her interest in the concept of the holographic paradigm theory (Talbot, 1992), and by a cerebral hemorrhage, she experienced in 1997 at the age of 44, which changed how she engaged with her practice. She later wrote about her experience in the scientific journal *Frontiers in Human Neuroscience* (Sherwood, 2012). Over the years, my interests in art and science had developed in parallel, but did not intersect until I took Sherwood's course while simultaneously finishing my thesis.[1]

Spending the majority of my time between the laboratory and the art studio, learning about illness and disability through visual art and in a research laboratory, changed the way that I engaged with both disciplines. Art had become what science already was for me: a practice of engaging with, understanding, and communicating stories, ideas, and information in a powerful and effective way. Just before graduating, a painting that I completed as a midterm project for Art, Medicine, and Disability titled *Learning/Unlearning*, created to discuss the language and experience surrounding illness was published in *Intima: A Journal of Narrative Medicine* (Harrison, 2016). Following this publication, I traveled to New York and learned more about the academic discipline of Narrative Medicine while attending the American Medical Student Association/Columbia University Narrative Medicine Summer Institute. Through these experiences, I considered new modes for the use of narrative arts in science and medicine, and how artists, writers, and scientists were already exploring novel ways to communicate important work in these fields.

Biomedical and clinical research are fields that have shown an increase in the use of written and visual narrative to draw greater public and academic attention to issues surrounding medical and therapeutic development, as well as the experiences of patient populations and healthcare providers. Within the last 20 years, many projects by scientists and artists have engaged with these issues in unique and compelling ways.

The Tissue Culture and art project, which began in 1996, uses a range of biotechnological assays and culturing techniques to grow living tissue for use as artistic media, containing "evocative objects [that] are a tangible example that brings into question deep-rooted perceptions of life and identity, concept of self, and the position of the human in regard to other living beings and the environment" ("The Tissue Culture and Art Project," n.d.). These pieces, created via collaborations by artists and scientists, seek to explore and question the use of emerging biotechnologies. Dr. Adam Zeman, a neurologist and professor of cognitive and behavioral neurology at Exeter University, published a collection of short stories titled *A Portrait of the Brain*, in which the author uses personal stories about the experiences of patients from his own practice, while simultaneously teaching his readers about the chemical and structural components of the nervous system (Zeman, 2008). In a similar vein, Dr. Kay Redfield Jamison[2] authored *An Unquiet Mind: A Memoir of Moods and Madness*, a vivid and intimate autobiography of the author's experience living with bipolar disorder (Jamison, 2009). Jamison's memoir, "lets patients read for

[1] *The Blood–Brain Barrier as a Therapeutic Target for the Prevention of Cognitive Decline* in the stress neurobiology laboratory of Dr. Daniela Kaufer.

[2] Professor of psychiatry at Johns Hopkins University School of Medicine who holds a Ph.D. in clinical psychology.

themselves how destructive not taking their medicine can be, it tells of the healing power of structure, psychotherapy and a social network. It tells them they're not alone. And, as critical, it shows…that the diagnosis needn't drain all the life from life," quoted from her biographical page on the Johns Hopkins University website (Mennitto, n.d.). Jamison's personal account, along with her other nonfiction works, poetry, expressive prose, and personal narrative mix beautifully with her captivating research on mental health disorders and the experience of being a psychiatric patient. Physician writers like Dr. Tweedy[3] (2015) and Dr. Danielle Ofri, M.D., have used narrative to speak openly about the experience of being a physician in training and how it intersects with race and gender. In addition, peer-reviewed publications such as "Reducing Stigma Toward People With Bipolar Disorder: Impact of a Filmed Theatrical Intervention Based on a Personal Narrative"[4] used a play written by an individual with bipolar disorder to educate and measure changes in stigmatizing attitudes among healthcare providers toward mental illness, similarly explore biases toward certain disease populations and identity groups both in healthcare settings and within society at large (Hawke et al., 2014).

Medical education has also made significant gains by integrating narrative practice into its curriculum as a way to foster better, more empathetic healthcare providers. In 2003, the University of Michigan Medical School created a required program for all first- and second-year medical students called "The Family Centered Experience" which uses "developmental and learning theory, longitudinal interactions with individuals with chronic illness, reflective learning, and small-group discussions to explore the experience of illness and its care" (Kumagai, 2008). Dr. Rita Charon[5] directs the Master of Science Program in Narrative Medicine, a two-year program that aims "to strengthen the overarching goals of medicine, public health, and social justice, as well as the intimate, interpersonal experiences of the clinical encounter" for individuals with backgrounds in the health and social sciences "who will imbue patient care and professional education with the skills and values of narrative understanding" ("Columbia University Medical Center | Program in Narrative Medicine," n.d.). Dr. Charon's theoretical framework for the use of narrative medicine taught in this program is the primary framework guiding the creative and reflective aspects of this project.

The Need for Narratives from Research Scientists Studying Psychiatric and Neurological Disorders

The writing and visual works of these scientists, artists, and physicians offer some examples of how, in an age where society has established art and science as separate entities, unifying these forms of expression can lead us to a deeper understanding of

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[3]M.D., author of *Black Man in A White Coat: A Doctor's Reflections on Race and Medicine.*

[4]*International Journal of Social Psychiatry.*

[5]M.D., Ph.D. at the Columbia University College of Physicians and Surgeons.

ourselves and our experiences and invite individuals from a variety of backgrounds to learn about fields they may otherwise feel excluded from. The democratization of narrative and expression in these fields makes them more accessible and responsive to individuals who hail from multiple cultural-linguistic backgrounds. Combining effective and novel means of presenting stories and information from both the arts and the sciences has the potential to benefit all of these fields by inviting more diversity, in the form of thought, identity, and experience, and by improving the transmission of information so that it may be more accessible to, and resonate with, a wider audience. It is essential that academia and the public adopt a holistic view of these domains in order to access the untapped power of communicating information in medicine and science with the use of art, performance, and writing.

Because of the humanistic quality of medicine, narrative in clinical care settings often has more visibility and is easier to access and understand than stories and artwork derived from scientists in the laboratory studying the biological substrates of a disease or developing new therapeutic treatments. This is perhaps because work in this area does not feel as relatable as being a patient or experiencing illness, and the complex scientific concepts that support and drive this research can act as a deterrent for people from nonscience backgrounds. But when we strip away the immense amount of requisite knowledge that researchers use to approach a question, we see that much of their work at its core is built on personal stories and interests that engendered a curiosity and a drive to understand some aspect of lived experience.

One area of research that deserves more attention, in light of an increasing societal focus on mental health and the nature of mental illness, trauma, and disability is applied scientific research that focuses on psychiatric and neurological disorders. Individuals from many walks of life have come forward with stories about the experience of psychiatric and neurological diseases such as depression, bipolar disorder, and post-traumatic stress disorder (PTSD); however, very few of these anecdotes regarding mental health come from scientists studying the mechanistic underpinnings of, or therapies for, these disorders. To complement a greater public understanding of the experience of these disorders, it would be advantageous to hear narratives from the scientists, whose work focuses on the mechanisms, management, and treatment of these illnesses, exploring what brought them to pursue this work and allowing them to bring their knowledge base to the public in an accessible way. To do so would not only augment the movement toward a more compassionate view of these disorders, it would also reveal that prior to accumulating vast amounts of knowledge and experience as a research scientist, the essential requisite to engaging in this work is often personal connection and the passion to pursue a scientific question.

Building on the foundational framework developed by Dr. Charon (2006), this project applies the three tenets of narrative medicine—"attention, representation, and affiliation"—as a means of communicating new discoveries in neuroscience research to a general audience. To demonstrate "attention," I interviewed three scientists at the University of California, Berkeley about their research investigating the underpinnings of a disabling psychiatric or neurological disease (PTSD, Epilepsy, and Dementia). These interviews focused not only on the premise and implications of the research itself, but also on the personal motivations driving each scientist to do this work. To create "representation," each scientist was asked to select a scientific image, generated from their studies, which depicted key concepts or data discussed in the interviews. I then transformed each of these images into a painting—an expressive representation with the potential to layer additional perspectives and meanings onto the technical image itself. Finally, to instill "affiliation," the completed paintings were presented alongside a short summary of the research as a means of increasing the visibility of these projects, improving the understanding of the biological causes of these diseases, and prompting empathy for the experience of psychiatric and neurological disabilities to a broader and mostly non-academic audience. To examine the effectiveness and outcomes of "affiliation," viewers of the paintings were asked to respond to this work in writing.

Methods

Narrative Medicine: A Theoretical Framework

Dr. Charon defines Narrative Medicine as "medicine practiced with the narrative competence to recognize, absorb, interpret and be moved by the stories of illness" (2006). Charon asserts in her 2006 text *Narrative Medicine: Honoring the Stories of Illness* that there is little in the practice of medicine that does not have narrative features, because clinical practice, the teaching, and the research are all indelibly stamped with the telling or receiving or creating of stories (2006). For this study, visual art and oral narrative are the main storytelling modalities represented. Charon's theoretical framework of narrative medicine focuses more often on written and oral narrative, as what might be encountered in a clinical setting, but it is easily applied to visual narrative. Charon's framework was chosen because it was designed to recognize patients and diseases, convey knowledge and regard, join humbly with colleagues and accompany patients and their families through ordeals of illness (2006), which is ideal for psychiatric and neurological disorders that are often stigmatized and poorly understood by the public. Charon's framework also aims to address communication difficulties between patients and practitioners, as well as scientists from different fields and those from nonscience backgrounds, by allowing all groups to orient themselves within the telling and receiving of stories. In *A Portrait of the Brain*, Zeman (2008) propounds that medicine is "an act of translation," in which various tests are translated into a diagnosis by a scientist or physician, and then the physician translates this diagnosis from complex medical language into one that the patient can understand. It is this failure of translation and language barrier that prevents the public and other scientists from becoming informed observers, let alone participants, in scientific and medical researches. Charon's framework for narrative medicine aims to create a space of engagement that allows information to be transmitted and received fully in an attempt to bridge a divide in knowledge between two seemingly disparate entities so that all parties feel acknowledged and understood.

Charon (2006) describes the “triad of attention, representation, and affiliation” as “the three movements of narrative medicine”. For this project, a preliminary understanding of the movements of narrative medicine is used to guide the reception and reflection of the research and stories of the scientists featured. The end goal is to explore the application of this framework toward improving the communication of basic science research and in doing so to continue to expand and develop the potential uses of this framework beyond the doctor-patient relationship.

The first movement, “attention,” is the complex act of listening and receiving information communicated verbally, nonverbally and through images. Attention generally entails a “suspension of the self” so that the listener is fully present, empathetic, and able to “bear witness” to the narrative of the other, giving the recipient of the narrative the ability to absorb it fully and avoid superimposing their own narrative or coming away with an incomplete or entirely different narrative than what was communicated. The listener inhabits the story by becoming a vessel for the narrative, or as Charon (2006) says “the bounty of narrative medicine unfolds through the surrender of oneself to be used as a creative instrument for the representation of another” (p. 149). “Representation” is equally if not more complex than attention. Charon (ibid) notes “vast amounts have been written about the actual creative processes involved in perceiving or imagining and then rendering a situation…either ‘real’ or ‘imagined’ in language” (p. 136). In her text, Charon (ibid) draws upon the work of Henry James and Walter Benjamin, who discuss artistic representation as having its origins in the experience and perception of actual life, and how this perception is expressed and processed through the viewer so as to extract meaning and value that is imbued with that experience or narrative. In the practice of narrative medicine, Charon (ibid) asserts that attention cannot be fully achieved without representation, in part because the experience gained from attention cannot be actualized without the reflection that representation demands of the recipient of the narrative. It orients the recipient in this narrative and allows them to experience it more fully and with greater accuracy, or as Charon (ibid) writes, “representing these events enables us to attend to them” (p. 139). Charon (ibid) sees attention and representation as “reciprocal and collaborative processes” that occur simultaneously, so that both entities learn more about the other and themselves. One entity attends while the other represents, and then the roles are reversed. This reciprocal relationship leads into the final movement of “affiliation,” a culmination of the first two movements that drives recipients of narrative to create contact and take action based on that narrative. In the clinical setting, “affiliation are the outcomes of narrative work—healing affiliations with patients and collegial affiliations with…nurses, doctors, and social workers”, and Charon (ibid) provides such examples as “mentoring communities with students, individual partnerships with patients, professional collectives with colleagues, and community networks with members of the lay public” (p. 150).

Interviews and Images from the Scientists

To demonstrate the "attention" component of narrative medicine, 10–20-minute interviews were conducted with three scientists from the laboratory of Dr. Daniela Kaufer at the University of California, Berkeley, a neuroscience laboratory that focuses on stress-related illness, located in the Li Ka Shing Center for Biomedical and Health Sciences on the university's main campus. Selection criteria were based on the availability of the interviewees and whether their research aimed to study the biological underpinnings of, or development of a therapy for, a psychiatric or neurological disease. Prior to the interview, interviewees were asked to select an image from their research that was meaningful to them. The interviewees included two Ph.D. candidates, Aaron Friedman and Vlad Senatorov, and the principal investigator Daniela Kaufer.

Interview questions were designed to be few and broad, so as to allow the interviewee the freedom to shape their own narrative. The core questions and prompts for the interview included the following:

1. Tell me about your research and why it's important.
2. What brought you to engage in this research?
3. What is meaningful to you about this research, and do you have any personal connections to it?
4. What brought you to choose the image that you did?

Visual Responses (Paintings)

Presentation to Responders and Responses from Viewers

Three paintings, one based on each of the images and interviews provided by the three scientists, were generated to exemplify the "representation" movement of narrative medicine to serve as the visual responses. The paintings were acrylic and mixed media on canvases of varying sizes. Photographs of the paintings were displayed in the form of a digital gallery catalog and sent via email to an audience of responders with accompanying text that provided context for the project and instructions for writing and submitting their written responses. Responding participants were first presented with a brief description of the epidemiology and symptomology of the disease of focus, and a description of the research premise and methods of each of the research projects described by the interviewees. Then a photograph of the original research image was shown and below that the artwork generated as a response.

The five responders were instructed to "take a moment to compose one single written response, no more than half a page (about 500 words), in any style you prefer. You can comment on what you liked about the presentation, what you learned, what you want to know more about, any feedback you might provide or anything else you would like to discuss. If you wish, you can comment on all three paintings in your response, or choose one or two that resonated with you".

Results

Interviews and Images from the Scientists

1. **Vlad Senatorov**

The first interview was conducted with Vlad Senatorov via Skype. Vlad is a doctoral student researching how epilepsy and cognitive decline can develop after traumatic brain injury or as the result of aging, as both can encourage the breakdown of the blood–brain barrier (BBB), a specialized collection of cells that forms a protective layer around the blood vessels in the brain. When this barrier breaks down, a protein from the blood called albumin leaks into the brain and interacts with a type of cell called an *astrocyte*, which make up part of the BBB. This interaction, which occurs at a site on the astrocyte called the "Transforming Growth Factor-beta receptor," allows astrocytes to act as first responders in detecting the disrupted BBB. In turn, the astrocytes unleash an injury response, causing a cascade of changes in the normal functioning of the brain, which can result in the development of epilepsy and cognitive decline.

In reflecting on the impact of this project, Vlad notes, "all of these different disorders, like cognitive decline and epilepsy, have been considered very distinct diseases with distinct etiologies. Now that we know more about the actual biology of how the disease progresses and what the early triggers are, we are understanding that there are a lot of common things that are shared between these diseases, especially very early on. The same things go wrong, and that's why looking at the TGF-beta pathway following blood–brain barrier disruption is very interesting because we believe that it's a very early and significant target that is shared among many different diseases, not just epilepsy and cognitive decline but also things like cancer, tumors, and stroke, which can also cause epilepsy. So, figuring that out and learning more about that will teach us not just about specific symptoms of diseases like epilepsy and cognitive decline, but about general disease pathology and what causes diseases to manifest in the human brain." When asked why Vlad chose the image he did, an image of a mouse brain taken from under a microscope, he responded, "it's probably my favorite picture that I have ever taken from a microscope, and I think it's really cool for a lot of reasons. The first reason is that a lot of people really don't think about scientific data as art, but anybody can look at that picture and see the colors and the shapes and the way things are organized and spread out. You can look at that picture without having a science background and think 'wow, what is that? I want to learn more about that.' The other reason is that it's not only beautiful, it's also informative, and it shows us four different stains [of different brain cells and proteins] and how they relate together, overlay and co-localize."

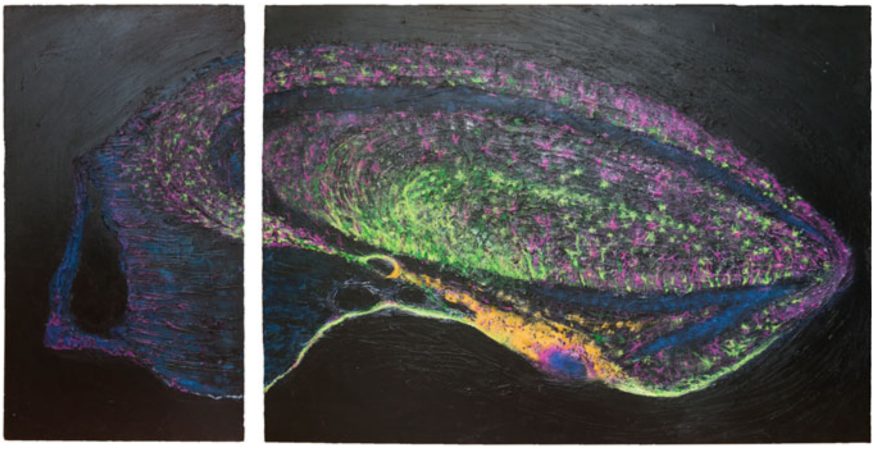
2. **Aaron Friedman**

The second interview was with Aaron Friedman. In his interview, Aaron began describing his research on PTSD by discussing how frightening memories in a healthy individual tend to be more vivid and salient than a regular memory, but that the fear or anxiety is "more or less contained to the event itself." His research focuses on "how those same processes may become pathological in those with post-traumatic stress disorder and basically why it is that in some cases, instead of being constrained to that one particular moment, those memories can be triggered again and again, and the aspects of that fear and anxiety can be brought very painfully into the person's life in situations where they are not in danger." To do this, Aaron studies neural stem cells in the hippocampus. "These are stem cells that will generate new neurons in the brain of the adult human or animals, and it's one of the few places where there are new neurons that are being created across the life span." In addition to being a scientist, Aaron also reflected upon his artistic background when we spoke about what drew him to his line of work. "When I was first starting to decide whether I wanted to go into biology I was actually also very interested in the literature and art when I was an undergraduate student," He began. "Part of the reason I was really drawn to these things was that on a personal level one of the more satisfying things is to understand other people's experiences and point of view and why they feel the way that they do, and how they think about things. And I think that is particularly interesting in a disease context when somebody has something like PTSD. In some way, their experiences are reminiscent of maybe a more normal experience, but somehow more different and extreme from the average experience. Because of my background in art and literature, I also care a lot about what the methods are by which people can understand their own experiences and express themselves. One of the things about disease is that it is not just debilitating physically, but also when someone is struggling with a disease, there may be some part of themselves that is occluded or suppressed by having so much of their life preoccupied by disease." When asked about why Aaron chose the image that he did. Aaron said, "I think these images are so powerful, because the research methods are in some cases for the first time actually seeing something real about the disease; what the disease actually is. Going beyond the symptoms and being able to measure something or look at something that has been hidden or unknown. That's part of what is meaningful to me about these images. It fits into the larger sense of why I wanted to become a scientist in the first place. I remember in my first introductory biology course, looking through the textbook it was kind of the first time that I had the opportunity to look at a lot of different microscopic images of all kinds of biological structures, and from that there was this very interesting feeling of awe that there was this whole hidden world that describes how we work as organisms and how we function that's almost invisible because it's so small… Through these kinds of images, we are able to see and do almost magical things like cure diseases that could not be cured before. It's a kind of hidden world we can only see if we learn how to look".

3. **Daniela Kaufer**

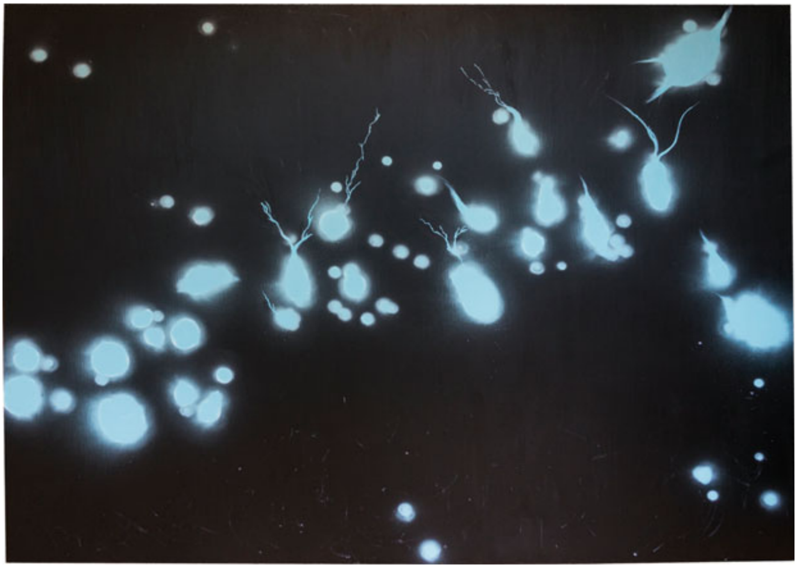
In my last interview with Daniela Kaufer, we decided that rather than an image, it would be interesting to use a video to show responders a rodent behavioral assessment task called the Morris Water Maze. The Morris Water Maze is a classic memory test commonly used with mice and rats, one that I encountered performing research as an undergrad. The maze is typically a large tub of water that has been made cloudy by coloring the water with white, non-toxic acrylic paint. Submerged just below the opaque surface of the water is a hidden platform, which is not visible to the mouse but can be discovered by accidentally swimming across it. The mouse typically has about a minute to find the platform before it is taken out of the water, and this is repeated across several sequential trials. By measuring the amount of time needed to find the platform, researchers can distinguish between mice with good memory, which are able to remember and swim directly to the hidden platform, versus impaired mice that struggle to remember the platform location and continue to search randomly, even after several learning trials. I wanted to choose a reference image and create a painting based on the idea of how data from behavioral experiments in animals could be used to study disease pathology in humans. I chose a short forty-second video of a rat swimming in the Morris Water Maze, found on Youtube.com (James, 2015), as the source material to create my painting. When I was able to speak to Daniela later on and present a photograph of the complete painting *The Morris Water Maze* (See “Visual Responses (Paintings)” below), she commented “It’s a fantastic choice. I think the fact that in the picture you have a human hippocampus, and over it the rodent modeled to study it. I love that. And that the human hippocampus itself is sort of the maze that they might need to find their way in. And the hippocampus, of all places, is mapped so well, so to choose that is amazing.” Earlier, Daniela had spoken about the advantage of using rodents to study disease, saying “The fact that we can move all of this work to rodents and ask [a] question in a rodent… really when you think about the types of questions that are of interest to me, they are the types of questions one would really want to ask in a human population. It was always clear to me that I didn’t want to do human research because I want the mechanistic answers, and I want a clean way of asking those questions, and in real life, there is no clean way [with humans]. When you have early life stress you are very unlikely to never see stress again in your life after, that’s just not the way life works. But with animals, you can imagine any scenario you want and just recreate it in a laboratory.” As the principal investigator of the laboratory, speaking with Daniela last provided the advantage of tying in all the elements of the first two research projects together. Reflecting on the spectrum of research projects being conducted in her stress biology laboratory, she noted “cognitive decline really is a much more recent thing to the laboratory. The overarching theme is really plasticity and how the brain works with any kind of perturbations that come to it. And, historically we were very focused on stress and how stress changes that, and the particular interest to me was actually critical periods when stress comes in specific points in time, so, early life stress, or in adolescence. Aging is looking at the other end of that, and how over the lifetime the brain has to deal with things that are happening to it. Stress being one, injury the another, and stroke, and so on. And I think that stemmed into many different things… when I just started as a graduate student, my project was very focused on stress, and then Alzheimer's, and then through the years it weaved in and out in different ways. But that's the big story, I think, in my mind. The really interesting questions are: how do you look at the different axis of function: cognitive, emotional, social, altogether coming into what we think is normal behavior, and then things [such as various life stressors] come across your way… and then so that is the very big picture and we are sort of looking at things that tell us about one thing in time. I think along the way we got glimpses into the resilience mechanism and brains that do better with some amount of stress. I don't think there are any brains that do better with some amount of injury, but I think there are individuals who do ok with that".

Visual Responses (Paintings)



***Mouse Brain*, 2017, Acrylic on Canvas, (24 x 68 x ¾ Inches)**

Vlad's statement "you can look at that picture without having a science background and think "wow, what is that? I want to learn more about that" on his multicolored photograph of a mouse brain similarly called out that sense of awe upon first seeing it. His next statement, "the other reason is that it's not only beautiful, it's also informative and it shows us four different stains [of different brain cells and proteins] and how they relate together and overlay and co-localize," made me feel as though it would be important to bring the center structure away from the surrounding colors and let it stand on its own. The resulting painting allowed the brain's fluorescent patterns to glow while suspended in black. The painting is also three-dimensional, allowing the viewer to appreciate the different textures of each of the distinct regions.



***New Neurons,* 2017, Acrylic on Canvas, (64 x 82 x 2 Inches)**

New Neurons was inspired by Aaron Friedman's interview when he described his first experiences looking at microscopic images and he felt "there was this very interesting feeling of awe that there was this whole hidden world that describes how we work as organisms and how we function that's almost invisible." In an attempt to embody Aaron's statement in an art piece inspired by the glowing blue neurons photographed in his research, I reproduced a painting very similar to the reference image, but on a much larger scale, hoping to capture this sense of "awe" as the viewer looks at these new neurons.

***The Morris Water Maze,* 2017, Mixed Media on Canvas (68.5 x 72 x 2 Inches)**

Painting *The Morris Water Maze* provided an interesting challenge. The reference "image" was the broader concept of the behavioral assay, so creating a visual response for this interview and research came with a lot of flexibility, while also carrying the caveat of communicating the research visually in a way that could be understood and appreciated with some context. I felt that superimposing the assay onto a close-up image of a human hippocampus, the large, twisted figure in white, could represent how we use animal models to understand the mechanisms of human disease.

Responses from Viewers

In total, five of the six responders chosen were able to send their written responses, all via email. Each responder also wrote a short biography to accompany their response. The biographies of the responders are included to help convey the background that may have informed their perspective as they composed their responses.

Hope Henderson[6]

"My favorite image was 'New Neurons.' The image is really pretty—it looks like a starry night sky, and the new neurons are comets. It makes me curious about the growth process: when do we grow new neurons? Are they continuously being made, or are they made in response to stimuli? And how do new neurons encode old memories? I imagine that for some people the fact that we make new neurons represents hope: hope that we can learn to think and feel and respond in different ways. Hope that we can overcome PTSD.

The 'Mouse Brain' image was very beautiful. I encountered it as a piece of art whose beauty was to be admired and gazed upon, but that effect was so strong that it didn't inspire my scientific curiosity, but rather kept me in a place of purely visual response.

The 'Morris Water Maze' peace was creepy. This has always struck me as a sad task: and making them swim around, with the ones who are suffering cognitive loss being forced to swim more, desperately looking for the underwater platform, so they can rest. The image of the mouse in this piece looks to me like a mouse pelt or a flattened mouse. It's so small next to the giant brain maze that the mouse looks sure to get lost. This image emphasizes the cruelty of this particular experiment."

Nicole Yeghiazarian[7]

"Topography figures prominently as a theme across 'The Morris Water Maze's' many different contexts. Mice in the Morris Water Maze swim to find the platform in cloudy water as part of a memory test. The ridges and furrows made by acrylic are reminiscent of gyri and sulci, tying the topography of the canvas to the topography of the brain. The texture of the piece serves as an element that is aesthetically pleasing, informative, and symbolic.

Texture serves as a dominant element in 'Mouse Brain.' In this piece, the texture in the black draws the eye along the curves of the brain. This contrasts with the texture within the piece that is more granular. The texture varies with the different colors, calling to mind how the image is of a composite. The way that superimposing pictures form composite images, varying colors and textures compose the depth of the painting.

The scientist's relationship to their laboratory animals is explored in both pieces. The use of a mouse pelt in 'The Morris Water Maze' reminds the viewer of the inevitable death of these animals. Through their lives and deaths, we learn about the mind and may better serve humanity. The mouse pelt is used as a visual element but also immortalizes the living creatures that enable our discoveries. In 'Mouse Brain', the mouse is seen in a way that is larger than life. An informative image

[6]Hope Henderson grew up in New England, where she studied biology and bioethics at Brown University. She is currently a graduate student at UC Berkeley, studying the role of mitochondria in health and disease. She enjoys reading, writing, quality time with her cat, and cooking delicious spicy food.

[7]Nicole Yeghiazarian is an undergraduate researcher at UC Berkeley in the Psychology Department.

is transformed into a beautiful painting, changing the mouse from test subject to a subject of art."

Mark Spero[8]

Mark's response focused on *The Morris Water Maze* exclusively, as it resonated with him on a personal level. He began by describing the dementia that his grandparents had experienced and how "it was interesting to attempt to relate this piece to description of dementia, especially due to my own experiences seeing how people react to losing their memory…the mesmerizing quality of the white hippocampus reminded me of how cloudy my grandfather's memory is becoming, and how at times he seems to turn off, or at least be unable to turn on enough to engage with what is going on. The mouse added to this idea, seeming to embody the way my grandfather attempts to find some memory or word which is now slightly hidden from his view." In regards to the presentation of the piece, Mark commented that "for every piece, and for 'The Morris Water Maze' in particular, I wondered what it would be like to see them before reading the descriptions. I do not think all art must stand on its own without any explanation, and I think these pieces are most rewarding when viewed while thinking about the specific disorders and the specific physical origins of the piece itself. Maybe this is because I was able to relate the pieces to both the very real lived experiences of those who have the disorders, as well as the real research being done on the disorders. The descriptions made my viewing of each piece a more grounded experience that I could easily relate to neurological disorders and research."

Owen Kent[9]

Owen responded to all three paintings in the form of a Haiku, each with three stanzas. Owen's Haikus were rich with references and imagery spanning mysticism, religion, ancient and popular culture, and the literature to respond to the written and visual information of each piece. As an example, his Haiku "Morris Water Maze," responding to the painting of the same name, read as follows:

One.

Swimming milky sea
Fear. Water. Drown. White Giant.
labrat revenge Now

Two.

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[8]Mark Spero was born in San Francisco and is recent graduate of Grinnell College, where he studied poetry and music business. He is currently living in the San Francisco Bay Area and primarily working for the National Public Radio show "City Arts and Lectures.

[9]Owen Kent is a filmmaker, visual artist, and entrepreneur. Following his passion for mathematics, he found himself studying at UC Berkeley at the age of 16. Having been diagnosed with a rare genetic mutation at the age of 2, his life and artistic vision have been dramatically influenced and inspired by the surgical-style aesthetic experiences afforded to him. Mr. Kent is presently producing two feature films, a psychological thriller and a documentary surrounding its production, as well a four-Dimensional "self-portrait" made from recycled medical equipment.

Marooned on Earth, soon
Fifth di-men-sion-al siren
We are all rats now

Three.

Occult ritual
Hippocratic Mikvah bath
White_Dragon_Rising

Benjamin Schaub[10]

Benjamin's response focused solely on *New Neurons*. Benjamin had been able to view the piece prior to reading the information on PTSD provided in the digital catalog, and began by saying "a kind of naïve captivation overtook me… I thought to myself 'How beautiful to see an image of new neurons! Who knows what they are encoding, or what corners of the mind and the individual's life experience they will come to represent?'" but then realized how the context provided by the explanation of PTSD altered the paintings intention for him in a very moving and meaningful way. "After reading the accompanying explanation…I was struck by the use of the word 'trigger' to describe instances when the person experiencing PTSD is returned to the pain of their traumatic memory by stimuli in a seemingly innocuous set of 'unrelated' circumstances… In an actually quite similar sense, the word 'trigger' has arisen in social justice discourses in recent years to describe the phenomenon of subtle or mundane expressions of oppressive circumstances evoking very painful reactions in subjects of that oppression, because of their reminiscence of instances or longer, accumulated experiences that have been traumatizing. Like most social justice language, this term has been swept up in a destructive frenzy of right-wing media and academic retaliation accusing the millennial generation who has begun using 'trigger' in this context of being overly sensitive and/or overly self-involved. Social justice advocates in this context are often compared with other generations who, far from being susceptible to 'unreasonable' responses to mundane triggers, responded (according to this narrative) to difficult circumstances in some vaguely more constructive or productive way. The aim of this notion is of course to dismiss the actually rather late arrival of the obvious into public discourse: that people relive their trauma due to innumerable stimuli both 'actually related' to their original experiences and not. I now have a renewed sense of hope and in seeing this painting and reading its accompanying text, because it seems that in this specific context, it is science that is catching up to people's reporting of their own experiences. I hope that Friedman's

[10]Benjamin Schaub is a freelance researcher, writer, and editor living in Berkeley, California. His research interests include contemporary political theory, theories and policies of international security, and the functional relationships between domestic and international laws. He has worked mainly on projects with academics at UC Berkeley, University of San Francisco, and the University of Cambridge. In our age of proliferating challenges of a complexity we could not have foreseen, he hopes new paths of interdisciplinary cooperation like the one represented by this art will continue to emerge.

research and other science like it can act as a reinforcement for people to be taken seriously, from the home, to the hospital, to the university, to the street, when they report that circumstances that people outside their identity group may very well not see or understand the source or links of present circumstances to pain that is nonetheless real and genuinely recurring. The art that this research accompanies makes this hope concrete. In our age of anti-intellectualism and 'alternative facts,' despite the dearth of elected officials willing to listen, I still believe science and art, at their best, are our most reliable way 'forward.' This painting bears a certain witness to both research and lived experience even as the notion of 'triggers' for trauma is more extensively explored in the laboratory, and continuously defended in politics by those who have always known this nuance of trauma. Even if we will not be believed right now, the painting seems to retort 'There. You don't believe? New neurons encode trauma. Here, let me write that on the wall where we can see.'"

Discussion

This project aimed to use neurological themed art to invite individuals from different backgrounds to learn more about neuroscience research investigating psychiatric and neurological illnesses, the desired outcome being that the participants would acquire new knowledge about this research and these disorders by giving them the agency to respond to images and descriptions of it. The question presented at the beginning of the chapter, as to whether a participatory art project has the potential to confer more interest and give the viewer a unique way to learn new information, as compared to traditional ways of presenting scientific research via academic texts, is answered in the work of the five responders. All five of the individuals were in some way interested in or moved by the artwork and accompanying descriptions of the research, and the intention of the project was that responders would come away with new knowledge of the research or its impact, which was also achieved at some level by each responder. However, what is also encouraging about these results is the fact that this project engendered the desire to know more, or prompted the responder to reflect upon some aspect of the experience of a patient with the disorder, or the future implications of the research presented. Science, in the spirit of inquiry, often does not simply aim to answer a question, but also aims to give rise to new questions that drive the field forward. The manifest function of this project was to impart new knowledge upon an interested audience and give them the freedom to respond to it, but seeing the responders come away from this project with what appeared to be an increased sense of curiosity regarding some aspect of the research or what it's future implications might be extends beyond the original desired outcome. This expression of a desire to know more and to wonder was also expressed very uniquely by each responder; ranging from observational writing to personal reflection and even through poetry.

One of the advantageous aspects of this project, in addition to being an area that could use improvement, is the small sample size. Having a smaller group of participants to represent how a project like this might be carried out allows for the appreciation of the eclecticism of responses one might receive from participants, and provides a sense of the intimacy of engaging with the individual narrative of each participant and how they might represent what they learned and what they want to know more about. It might be beneficial to scale up the number of participants (both interviewees and responders) and perform some type of qualitative and quantitative analyzes to observe any emerging themes, common questions or to explore avenues for improving the delivery of information in a project like this on a large scale. In addition to using the interviews and responses for data, one could also develop a short survey to obtain more directed feedback on some aspects of the project such as the clarity of the directions or the way some part of the project was presented.

Responders who participated in this project were only able to engage with the artwork and the description of the disorders and research digitally, because finding an appropriate venue for displaying the artwork that would be accessible for all participants was a challenge. However, because visiting a specific gallery space may not be possible for all individuals who want to participate, this particular application of this project, although it is a different way of engaging with the art, is still effective and accessible given the results. If possible, one could perform a side by side comparison of how an in-person viewing might differ from the method used for this publication. In certain teaching scenarios, both methods of presentation could also be used.

In my methodology, responders were first given a basic summary of the research (including the epidemiology and symptomology of the disorder, a description of the research, and the original reference image) to inform their viewing of the painting. An alternate method, in which the visual art is presented without context to a naïve audience, could potentially have a large impact on the quality of the audience's perception and response. The responder Benjamin Schaub was able to view *New Neurons* out of context, and then commented on the shift to understanding the implications of the image after reading the descriptions and revisiting the work, and Mark Spero wondered what the experience of seeing the image of out of context would be like, but also commented on the fact that viewing the image with the context was a "more grounded experience." These two examples provide some level of comparison between ordering the digital presentations differently, and the results indicate that the ability to view the work in context of a description of the science is important to facilitate understanding of the information provided.

Lastly, it may be of benefit to increase the participatory aspect of this project for the responders. In an alternate version of this project, responders could become interviewers for the scientists, creating an interesting space of engagement between two individuals who may not otherwise have the opportunity to interact. Responders themselves could also visually respond to the chosen research images with their own visual, written or performance pieces, and encourage other participants to respond to their creations and the research that inspired them. This would allow more participants to exercise their right to express their cultural-linguistic identities through their narrative responses to this learning experience.

Conclusion

Inviting students and the general public to engage with science and medicine through the use of the visual and performing arts has the potential to disrupt the current paradigm of how information on science and medicine is communicated and to bridge the gap between such an audience and professionals in scientific and biomedical fields. Hearing personal accounts from scientists on the impact of their work, their personal interests and connections to it can have a profound impact on those learning about the research. Finding creative and novel ways of presenting and responding to information on this work could contribute to dissolving the perception of science and medicine as accessible only to people who appear to grasp immensely complex information with mystifying ease. In reality, these people are talented, but are more importantly very passionate about and connected to their work. This prerequisite passion and connection, to offer a challenge to our perceptions of those who may at first struggle with scientific concepts, is ultimately more essential to finding fulfillment and success in learning about science and medicine than skill alone. Making an effort to increase the accessibility of science and medicine through creative and flexible means represents an investment in diversity, equity, and individual potential by giving individuals from all backgrounds the opportunity to experience the joy and fascination of learning about work in these fields.[11]

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Chapter 15
Artists as Co-teachers in the Field of Medicine

Melanie Ekholdt Huynh

Abstract Medicine is both an art and a science. The importance of the *art* of medicine is because we have to deal with a human being, his or her body, mind and soul. The "art of medicine" has lost its sheen what the rapid advancements of science in course of time, which has made present-day medicine more sophisticated (S.C. Panda 2006). There is now a movement of reinventing the art of medicine. The awarded doctor and writer Abraham Verghese and others are now starting to include rituals, stories and the art of medicine in the curriculum of medicine. In this chapter, three examples of how to integrate art in three different learning situations are described—a group learning session of young doctors training to be therapists, a talk in the local hospital talking about the painful topic violence against children and finally a personal learning experience while the author is dialoging with an artist about his use of ADHD medication. As a child psychiatrist, it is natural to choose an art form, which is used by the young people. Music videos are easy to find on YouTube, for doctors and educators. It can be a rich, intense learning experience to watch a music video full of images, sounds—a mixture of visual art, music and lyrics. The narratives and the lyrics from three different music videos will be presented; "Monsters" by Eminem, "Fucking Perfect" by Pink and "Gangster Blues" by the Norwegian rapper Michael Kildal. The three different earning experiences will be described, followed by a discussion about how we together can explore the integrating of art in the curriculum of medicine and maybe other STEM subjects.

Music in Art

In this, Chap. 1 describes how the art forms of rap music and modern pop music may be used in an educational setting. As a child psychiatrist, it is natural to use an Art form familiar to young people. Young students can understand and connect with these non-traditional art forms. The narratives and lyrics from three different

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music videos: “Monsters” by the rapper Eminem, “Fucking Perfect” by Pink and “Gangster Blues” by the Norwegian rapper Michael Kildal will be described here and made use of. The focus will be on three different learning experiences, followed by a discussion on how we can explore the inclusion of Arts in science, technology, engineering, and mathematics (STEM) subjects.

Education in the Fields of Medicine

The vision of education in the field of child and adolescent psychiatry is to contribute to positive differences in the lives of children and families, through prevention and improvement of the services. As the field is multidisciplinary, we rely on one common theoretical concept called “the biopsychosocial model”, which is meant to help an array of different professions find their place and meaning in the complicated child mental system.

Borrel-Carrio, Suchman and Epstein (2004) describe a biopsychosocial-oriented clinical practice, whose pillars include:

- Self-awareness
- Active cultivation of trust
- An emotional style characterized by empathic curiosity
- Self-calibration as a way to reduce bias
- Educating the emotions to assist with diagnosis and forming therapeutic relationships
- Using informed intuition and
- Communicating clinical evidence to foster dialogue, not just the mechanical application of a protocol.

Their conclusion is that the value of a modern version of the biopsychosocial model should be used in applying medical knowledge to the needs of each patient.

Theoretical Framework

Humankind is probably the most complicated of all living species. Each newborn child is a miracle, but their development and survival are dependent on the surroundings and opportunities offered. In the field of child and adolescent psychiatry, our intention is to support the children and their caregivers in helping to better develop the children’s capabilities. It is quite demanding, and in this complex field, there are no simple answers. Pickersgill (2012) demonstrates how psychiatry is not a singular entity, but a form of complex sociotechnical practices. He proposes an approach which focuses on the relationships between scientific knowledge, biomedical institutions, social action and subjective experiences. He argues that by recognizing the multifaceted nature of psychiatry, we can create a process of "co-producing complexity in mental health".

Panda (2006) in his article "Medicine: Art or science?" provides an analysis of the origins of medicine and reminds us about the significant difference in teaching and practicing medicine today, compared to the past when medicine was conceived of as both an art and science. Duffy (2011) claims it has been over 100 years since the introduction of the biomedical model as the gold standard of medical training. Furthermore, he describes how medical doctors have become technicians detached from their patients, rather than artists in a science that serves patients.

I have been working in the field of child and adolescent psychiatry for 20 years and have experienced first-hand a gradual loss of relational focus with the patient. According to Fonagy and Clark (2015), the latest research points out that the majority of children receiving community-based mental health care do not show clinical improvement. This may be interpreted as an indication of a current practice, which has lost its aspiration as an art form.

Rethinking our style of therapist training is crucial to improve the psychiatric services. Not different to how the training of an artist is crucial for the final outcome of the art.

Artists are now included in the "Circle of Care" courses, a collaboration between the Clod Ensemble, a performing art company, and the Simulation and Interactive Learning Centre (SaIL) at St. Thomas Hospital in London (Wilson & Jaye, 2017). Health care professionals tell us how these classes help them to be more compassionate with themselves and others (Heath, 2016). De la Croix and her co-researchers (2011) describe a qualitative method by making thematic analyses and word frequency analyses on 978 written student materials (reflection and feedback). Students reflected on their experience of participating in workshops called "Performance in Medicine," lead by artists from the community. They reported that the artists had helped them improve their skills in communication and observation, self-presentation, self-care and also enhanced their sensitivity to cultural differences.

Nussbaum (2010) argues that through the effort in building an appropriate method of education, narrative imagination can be included in the lives and development of human beings. She sees novels as being particularly rich with regard to such an endeavour and also highlights the role of music, dance, painting, sculpture and architecture in cultivating capabilities of judgment and sensitivity, as they play an essential role in "shaping our understanding of the people around us" (Nussbaum, 1997). She asserts that an education based on narrative imagination can overcome barriers of nationality, race, sexual orientation and gender.

Kaleidoscope is a multicultural music project that was started in the Norwegian town of Bergen in 2004. Schuff (2016) describes how their method empowers youth. Young people from different cultural backgrounds share their music (songs, dances, and rhymes) with professional musicians and choreographers. Through these participatory, collaborative creative activities, a colourful music/dance performance is created and performed for a local audience. The founder of the kaleidoscope method, Hamre (2011), emphasizes that kaleidoscope is not a "social project", but an Art project, in which the participants are viewed as contributing performers.

Methodology and Discussion

Through my work at a training institution, I meet regularly with a group of young physicians training to be child psychiatrists. The medical education they receive in Norway is based on the biopsychosocial model, a so-called "circular" model (Borrell-Carrió, Suchman, & Epstein, 2004). Our mental health clinics for children follow a "linear" biomedical model in their initial diagnostic assessments and thereafter offer psycho-therapeutic treatment, and sometimes pharmacological treatment, depending on the diagnosis. The intention of this approach is to provide quality care based on clinical studies. The Change Factory is a Norwegian non-profit organization cooperating directly with hundreds of children. They ask professionals to modify their standard approach and instead tailoring treatment to each vulnerable children and young people they meet (Sanner, 2016). Professional training institutions are the most important places to facilitate a change towards a more flexible approach.

Within this context, how can I as a teacher counterbalance the overwhelming focus on rationality and "right" answers? How can I preserve and maybe nurture my didactic, pedagogic creativity?

The report "creative minds in medicine" (Puch & Mathew, 2014) claims that research has demonstrated that exposure to arts and culture in medical training helps practitioners to:

- develop higher levels of empathy, trust and self-awareness with patients
- improve observational skills which aid in making diagnosis
- interpret the personal narratives of patients
- cope with emotions associated with the care of patients
- deliver patient-centred care
- alleviate personal stress.

In the systematic review "A guiding framework to maximize the power of the arts in medical education", Haidet et al. (2016) found that the learning process can be enhanced, when students participate in the context of a group and the group itself undergoes transformative change. I asked myself: How can art be included in the training of future child psychiatrists?

The Effects of Including Artwork in a Group Learning Session

Introducing the word "professional identity" as the theme of the day, I invited my students to explore this concept together by watching a video where Rihanna was role-playing Eminem's therapist. I then gave each of them a sheet of paper with the lyrics of the song and asked:

Which phrases move you?

During one hour sitting around a table, each of them shared their thoughts and reflections. They were focused, curious and engaged, discussing complicated therapeutic issues.

For instance, we debated the issue of diagnosis, which can be both helpful and harmful for young people.

My Obsessive Compulsive Disorder (OCD) is conking me in the head
Keep knocking, nobody's home, I'm sleepwalking.

Maybe the diagnosis of OCD was useful for Eminem, allowing him to externalize his thoughts of craziness.

Cause I need an interventionist
To intervene between me and this monster
And save me from myself and all this conflict.

When should we just breathe and do nothing, simply sharing the difficult monster feelings with the young person in pain? When should we intervene as a therapist and do something to help the patient survive their pain?

Maybe I need a straight jacket, face facts
I am nuts for real, but I'm okay with that
It's nothing, I'm still friends with the monster

We also were caught by the ambivalence of needing a "straight jacket". The description of the chaotic, crazy feeling of needing help to calm down the inner monsters, but still having these monsters feel like friends. The obvious difference between child psychiatrists and Eminem is that our job is not artistic entertainment, but to help traumatized children and young people live life as survivors instead of victims.

I ain't here to save the fucking children
But if one kid out of a hundred million
Who are going through a struggle feels and then relates that's great

Eminem's main job is working as an artist, and maybe we, as child psychiatrists, share a common vision with Eminem: the hope that at least one child out of a thousand can have a better life by daring to feel and express their feelings.

Inspired by Donald Schon's concept of reflective practice (2001), I asked my student group what the pros and cons were of using music videos within a group learning session. I found the following feedback interesting and important to take into account:

- *It can be quite irritating to watch the video if I do not like the style of music.*
- *If the lyrics are in a foreign language and I don't understand them, I get stressed.*
- *There should be given a clear intention before the video is shown.*
- *If the reflective discussions take too much time, it can feel irrelevant for my clinical practice.*

Then these more positive comments helped give me confidence to continue exploring this as a didactic tool:

- *The video creates room for reflection and exploration of feelings. Going through the lyrics helped me reflect on the meaning of different words and difficult feelings.*
- *This type of group work gives variation and a kind of pause, because the message is given in another way, with more nuance and changing atmospheres.*
- *It was interesting to discover how we all see and experience the music video so differently.*
- *It inspires me to use music videos in therapeutic work with adolescents. It makes me think about my patients in another way.*
- *I learnt a lot about myself.*
- *I got to know the teacher.*

A Talk in an Auditorium

One part of being a professional in many different fields is communicating with the local community. As a child psychiatrist, my view is that it is an important part of our role in society to share narratives and stories from the young people we meet, off course anonymized. When I was asked to give a talk to surgeons and interns at the local hospital, Diakonhjemmets Sykehus, I choose the topic "violence in childhood". Young people are frequently treated at the emergency wards of local hospitals, when the pain of life urges them to do self-harm through cutting or overdosing on drugs and alcohol. The doctors working there are often tired, on night shifts and usually do not have time to listen to these young people and their family histories, which are often filled with psychological and physical violence. The main part of the work of a child psychiatrist is to explore the childhood stories and dreams of youngsters. In his TED talk, Verghese (2011) is famous for his focus on the patient narrative and the importance of "the doctors touch", especially in our new modern way of living. He argues that:

> Modern medicine is in danger of losing a powerful, old-fashioned tool: human touch.

I have experienced that the painful topic of violence easily overwhelms the public. They can become anxious and over-involved, while at other times reacting with hopelessness and disengagement. How could these overworked doctors become more involved in the painful topic of childhood violence? As a young therapist, I was profoundly moved by a woman who was the mother of a four-year-old girl, believing her social phobia made the life of her child difficult too. She asked to have therapy for this and by discussing her own childhood; she revealed sexual abuse by an uncle, which had gone on for many years when she was a little girl. The most traumatic event for her was in fact the feeling that her mother did not believe her, because she acted as if nothing had happened. This young woman told me she used music to calm down, and I naturally asked what her favourite song was. She answered Pink's "Fucking perfect". The video is a strong story about the life of a young mother. During three and half minutes, Pink takes us back in time. We first see the main character as a little girl in her kindergarten, then as a schoolgirl, then as a teenager and finally as a young mother.

Pink (2011) herself says:

> Cutting and suicide, two very different symptoms of the same problem, are gaining on us (the problem being; alienation and depression, the symptoms; cutting and suicide). I personally don't know a single person who doesn't know at least two of these victims personally.

One of the strongest moments of the video is when the music stops, and we see the red water of the bathtub, where the adolescent girl has cut the word "perfect" onto her forearm with a razor. There is a turning point for the character at this stage, and we see the young woman begin to paint large abstract canvases featuring many colours. Pink appears in the video singing next to her, in the end taking part in the girls vernissage, who is now launching herself as a professional artist.

The world of art is used actively in the healing of trauma through all types of forms: psychodrama, writing, dancing, etc. Bessel Van der Kolk (2014) describes a variety of ways to utilize art in his book: "The body keeps the score". Pink (2011) described the process of making her video as a "very emotional experience" and related the core theme of "Fucking Perfect" to her yet-to-be-born baby, saying, "I have a life inside of me, and I want her or him to know that I will accept her or him with open, loving and welcoming arms. And though I will prepare this little munchkin for a sometimes-cruel world, I will also equip this kid to see all the beauty in it as well". Maybe Pink wanted to establish hope with the happy ending of the video and thus remind the audience how art can be a way of transforming brutal realities of life into something unique and beautiful.

After a short introduction, I projected the music video onto two large screens. Each doctor had also been invited to think about one time they had experienced self-cutting behaviour. The images and music filled the auditorium for a few intense minutes. When the lights came on, I saw two senior doctors with tears in their eyes. I shared with the audience how I also had cried the first time I saw the video.

If doctors are able to be emotionally moved like this, will it help them to see the patients in a more holistic, personal and caring way? Crying is often a catharsis, a relief. In his chapter, "movement and movies in bioethics", Solbakk (2014) emphasizes

> that a kind of cathartic treatment is needed before the soul can have any hope of benefiting from moral or other forms of learning.

Solbakk's proposal of a notion of *tempered catharsis* as a concept insists on evoking in the audience only particular types of emotions, not any emotion,

> The notion of tempered catharsis may help in identifying bits and parts of theatre plays, movies and other forms of fiction for use (in ethics) teaching.

Hopefully, Pink's storytelling induced an emotion of compassion.

A Personal Learning Experience

As a child psychiatrist, I spend most of my time talking with young people about life, feelings and relationships. It can be quite meaningful, but also difficult to listen to while remaining empathic, especially if the young person has a completely different background than my own.

Looking back on my own therapist training 10 years ago, art subjects were introduced in just a few talks and workshops, and in quite an indirect manner. Wilson (2007) talked to us about therapists as jazz musicians and described this in his book, “Performance in Practice”. But he did not invite any artists to participate, nor did he play jazz music during the learning session. Now 10 years later, some brave senior lecturers have begun to share their artistic skills in the auditorium, and we do sometimes invite young musicians to play as well, but with an intention of relaxation and divertissement rather than education.

When a young local rapper appeared on the Norwegian Idol-like talent show, his lyrics instantly caught my attention, since they were different from commonly heard rap lyrics:

> Why should you judge yourself, when everybody else does it?

After the performance, he told the host how his drug experiences had influenced his lyrics and music. After a quick Google search, I found an interview where he explained how he was diagnosed with ADHD as a teenager. His subjective experience was that he began to use drugs because the doctors gave him Ritalin. ADHD is the most commonly diagnosed child psychiatric disorder in the world, and Ritalin and other psycho-stimulants are increasingly prescribed as treatments for ADHD (Singh, 2012). This was the first time I had heard that Ritalin could be a part of the cause of drug abuse. I felt a strong urge to contact the artist, Michael Kildal, and explore this possible connection. I had a “flashback” from a learning session, where my family therapy teachers had invited a young woman to talk to us about her drug experiences. I therefore got the idea to invite him to a group session with my junior doctors. I sent him a message on Facebook: would you like to come and talk about your experiences to my group of young therapists? His manager quickly answered: yes!

Some weeks later, eight doctors, myself included, were sitting listening to this young 25-year-old man describe how Ritalin helped him focus at school, while at the same time had giving him sleeping problems. His solution was to smoke cannabis in the evenings, which he accessed by “selling” his Ritalin pills. He also told us how writing song lyrics became his own therapy and how music helped him express himself. This is best described in the lyrics of one of his songs: Gangster Blues.

Gangster Blues-XZWER (His Old Artist Name)

From the time I was eight years
my daddy gave me nightmares
But now I feel the distance to my pain is like a light year
Thank you mama for every little thing you did
I know I made a lot of drama when I was a kid
And I know it wasn't your call when the doctors came and gave me Ritalin
But I quit the pill and the past is gone and the hash can't kill, so I blow the smoke.
I feel the gangster groove
Up in the buildin' I'm killin' my feelings 'n
I don't really know who the fuck I am dealin' to.

I discovered that I needed to learn more about his history to understand his story, so I asked him to write a book with me about how music became his therapy. The book title is: "In Love with Craziness—the Art of understanding the turbulent youth". In the upcoming documentary with the same title, Michael explains with his own words how he managed to give meaning to the suffering and pain by the creative process of writing the lyrics of his songs.

When I first contacted Michael, I thought of myself as the doctor and him as the patient. During our continued dialogues, I began to notice a shift inside myself and my relationship to my profession. A question appeared: what is valid information and knowledge? He was no longer only a patient, and I was no longer only a doctor or a child psychiatrist. I became a whole human being aware of my vulnerabilities and my lack of knowledge of the perspectives of young people I had been treating with ADHD symptoms. I could no longer invite only senior colleagues and experts in the field of pharmacology to teach in the training program. I realized that I now have to invite artists and patients as co-teachers in the training seminars, both in order to show their artistic skills and also to share personal experiences.

Some Final Words About Democracy, Creativity and Language

According to Nussbaum (2010), democracy is built upon respect and concern, and this is built on the ability to see other people as human beings, not simply as objects. She claims that radical change is now occurring in what democratic societies teach their young, because the arts are being cut away in virtually every developed nation of the world. In her view, the consequence is a global crisis in education. In her book "Not for profit: Why democracy needs the humanities", she shows us how the humanities and arts are crucial both in primary, secondary and university education. By stimulating critical thought, imagination and empathic understanding of the human experience of many different kinds of people, the arts make us able to sense the world in a much more connected way.

While Norway is rated as one of the most democratic countries in the world, my opinion is that the universities and educational systems in Norway are lacking a real democratic learning system. Educators try to transmit a lot of so-called “facts” and to “give knowledge” to the students, especially in the medical field. There has been a tradition of discussion and debate around the validity of known medical “truths” (Bjørndal, 2009). For example, the “fact” that Ritalin is a safe drug. Many educators have not been clear to their students that the knowledge base used in medical education is incomplete and constantly evolving. The consequences are that students do not learn how to deal with their own feelings of doubt and insecurity, especially the forms of doubt such as therapeutic questions, which are the keys to cultivate people’s minds and hearts.

Babaci-Wilhite (2016) describes in her latest research on human rights in language and STEM education, how the decontextualized, insular nature of knowledge being passed on, gives little opportunity for students to question the claims on which the knowledge is based upon. The context she based this on was science education in an African country. The context described here in this paper is professional development in a Nordic country, Norway. Babaci-Wilhite describes the use of African local languages. My proposal is to include artists and other non-academic voices into our education systems, so we can encourage one of the most important human rights, the right of participation and inclusion.

Some Final Words About the Role of the Artist

I originally thought about sharing my “knowledge” with the general public. But through the process of professionally sharing the narratives of young rappers and artists, I now have another point of view. I no longer believe this is the best way forward. It has now become more meaningful for me to include more of the population, represented by a range of different types of artists. I believe it is vital to have these kinds of people sharing their experiences and ideas within the educational systems of schools and universities. By including non-academic voices, we will be able to produce different points of view. Although this change is difficult, I believe it is necessary in order to avoid the harm that both medicine and formal education can do.

In our new digital landscape, it is quite easy to find music videos and films from all over the world. And it is easier than ever to project a trailer of a film within an auditorium, instead of inviting the actual artist to visit in person. But are there didactic aspects of the performance and engagement we risk losing by not inviting the artist? Trying to improve the complicated education system is quite challenging. Perhaps we could move beyond changing the content of the curriculum and instead invite artists to directly participate in the pedagogical work itself. By introducing and including artists, not just their artwork, could we more easily induce change within the educational world?

Henriksen (2013), concludes in his chapter "Power, powerlessness and creativity" by saying this:

> Artists can tell us something about the important striving necessary to overcome powerlessness. There are some important differences between artists and the rest of us. Artists have easier access to their own creativity, they are more disciplined and they have the experience and ability to target/set goals for their creativity. Creativity is a resource which has to be cultivated within and by the help of knowledge able to recognize it and make use of it.

Some Thoughts About Future Research

Could working with artists as co-teachers be an effective way of integrating art into medicine, mental health and STEM subjects? This is a question to explore in the field of child psychiatry. Maybe comparing the use of artwork presented as a pedagogical tool, as opposed to presenting the art alongside inviting the actual artist themselves to participate as a co-teacher, could be a research project? My hypothesis is that when you introduce an artwork without the artist present, you may inspire the students to explore the art form and include that art in their own life, but the students will probably have more distance to the topic you invited them to explore and you will end up with less engagement as a result. Inviting an artist into the classroom has the possibility to give students a much more intense and direct experience, even relating to students' own life dilemmas both personal as well as professional. It would also be interesting to explore how the whole range of STEM subjects could involve art and artists in different ways.

Concluding Remarks

Working with education and professional training only since 2016, I have been inspired mainly by my own teachers. By writing this chapter, I became aware of how my own learning processes deeply influenced my pedagogical choices. I believe that in exploring your own personal learning experiences, you may be able to find treasures, energy and the power to make changes in your field.

However, instead of just copying, we should in fact further develop and integrate art within education in close partnership with artists themselves. I believe that a real partnership can help us move forward much more powerfully. I discovered when writing this text that the field of medicine has applied art in medical education across the ages. By integrating art in the education of more traditional STEM subjects, it may be useful to follow the advice of the report "creative minds in medicine" attached in this chapter as an appendix.

Appendix 1

Best Practices for integrating Arts in STEM Subjects

- **Understanding context**. All parties involved should understand the needs of the ***STEM students*** being served and the ***available resources*** for implementing arts in STEM subjects.
- **Funding the intersection (Art and STEM subjects)**. Funding can be helped by ***strategic alliances*** and better research.
- **Addressing accessibility issues**. Artists, students and educators all have various types of ***accessibility concerns*** that need to be addressed.
- **Managing partnerships**. Collaborations can help with the sharing of expertise and resources.
- **Disseminating research**. Research will help bolster the case for arts integration in education of STEM subjects.
- **Educating the students, the educators and artists about the intersection**.

Education will strengthen and increase understanding of the benefits of the arts in education of STEM subjects.

- **Ensuring the equality of all participants**. Different workplace traditions and regulations and diversity are all issues that need to be considered in the arts and STEM subjects.

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Afterword

Theoretical and Practical Implications for Linguistic Rights in STEAM

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The collection of chapters in this volume edited by Zehlia Babaci-Wilhite, *Promoting Languages and Human Rights in Education Through STEAM: Science, Technology, Engineering, Arts and Mathematics Education*, raises many intriguing questions about knowledge, society and development and what forms of education are most needful for young people today, particularly for members of non-dominant linguistic and cultural groups. In the 1990s and at the turn of the last century, UNESCO, the World Bank and other organizations advocated for Education for All (EFA), with a shift more recently to demanding Quality Education for All (QEFA), which on the face of it is a motherhood issue on which all could easily agree.

Yet it turns out on closer examination that the issue of quality in education is rather mysterious. At the same time, discussions of education are beset with terminological ambiguity. In English, for example, quality in education can refer both to the presence of desired characteristics among learners and an effective process or system. So when English language literature talks about "quality education", it is ambiguous which is meant. It most frequently refers to the second, the effectiveness of the system in bringing about certain goals, while what the aims of education are in fact frequently assumed is much more than clearly defined and argued for. Chinese uses different terms for these two meanings: 素质 (sùzhì) in the first sense, and 质量 (zhìliàng) in the second (Kipnis, 2006), more clearly distinguishing quality/qualities of people involved in education: learners, parents, teachers, administrators, etc., from quality/qualities of the education system. STEAM and STEM educations are for the most part curricular approaches which have underlying educational aims, which together can suggest particular pedagogical approaches. This suggests that there is general agreement about what in fact education and the curriculum are. While in popular understanding, curriculum is

Z. Babaci-Wilhite (ed.), *Promoting Language and STEAM as Human Rights in Education*, https://doi.org/10.1007/978-981-13-2880-0

Table 1 Bernstein's curricular categories

Framing	Classification	
	Low	*High*
Low	**Integrated code**: Fuzzy subject boundaries; weak restriction on teacher/student choice	Strong subject boundaries; weak restriction on teacher/student choice within subject
High	Fuzzy subject boundaries; strong restriction on teacher/student choice	**Collection code**: Strong subject boundaries; strong restriction on teacher/student choice within subject

Source Adapted from Bernstein (1996)

synonymous with *course of study* (Connelly & Clandinin, 1988, p. 4), among educators, policy-makers and researchers, meanings range more widely. At its simplest, the curriculum is seen as a list of topics to be covered by a teacher in a particular course and overlaps in meaning with *syllabus*. At its broadest, the notion of curriculum encompasses all experiences that a student may undergo as a result of schooling (Miller & Seller, 1990, p. 3), what Kelly has called the *total* curriculum (2004, p. 4).

However, there is controversy over whether all that occurs as part of schooling is educational. Kelly distinguishes *education* from *training, indoctrination, conditioning* and *instruction*, while Eisner makes a similar distinction between *teaching,* which is part of education, and *instruction,* which is part of training (2002, pp. 160–161). Eisner further follows Dewey (1938/1997) in distinguishing *educational* experiences in schools from both *non-educational* experiences, which have little positive or negative effect on learning or growth and *miseducational* experiences, which in some way limit or hamper learning or growth of the student (2002, pp. 37–38). Education versus miseducation for Dewey is related to his concept of *growth, or* as Eisner puts it "the extension of human intelligence, the increase in the organism's ability to secure meaning from experience and to act in ways that are instrumental to the achievement of inherently worthwhile ends". Miseducation then prevents such extension of human intelligence, or perhaps even reduces it, while non-education has no effect one way or the other (2002, p. 37). For Kelly, the key aspect of content and activities in curricula that qualifies them as *educational* is that they are included because they are of *intrinsic* value in and of themselves and are not included for *extrinsic* or *instrumental* reasons, as a means to achieving some other ends or ends for the benefit of other persons (2004, pp. 47–48). Anyon's work comparing elite schools, middle-class schools and working-class/minority schools has shown that the conception of education enacted in them ranged widely on the continuum from liberal education for the elite to training for non-dominant groups, which could perhaps be seen as education for the elite; non-education for the middle class; and training/indoctrination for the least dominant groups.

Judgments of quality vary with who is making the judgment (Beeby, 1966, p. 12); thus, evaluation of educational quality should include assessments of worth by all stakeholders (Chapman & Carrier, 1990, p. 14). Yet, educational systems tend to assess quality largely based on impersonal technical criteria: efficiency, standardization and consistency. As Olssen, Codd and O'Neill put it, "The quality of education is reduced to key performance indicators, each of which can be measured and reported" (2004, p. 191). In reference to the university in North America, the Canadian philosopher, George Grant, reminds us somewhat pessimistically, however, of the difficulty for members of an epistemic community to critique their own practices from their own perspective:

> We are unable seriously to judge the university without judging its essence, the curriculum; but since we are educated in terms of that curriculum it is guaranteed that most of us will judge it as good. The criteria by which we could judge it as inadequate in principle can only be reached by those who through some chance have moved outside the society by memory or by thought. But so to have moved means that one's criticisms will not be taken seriously from within the society. (1969, p. 131)

An additional educational debate is about who defines what knowledge is and what the relationship should be of domains of knowledge to each other: what is their place within the curriculum, and what are the boundaries between them. Several frameworks are useful for the analysis and comparison of approaches to the questions: what should be studied, by whom, for what purposes. One approach to studying curricula consists in determining their orientation to knowledge and learning, and approaches to teaching that derive from these orientations. Miller and Seller (1990) propose a division into three overall types of orientation: transmissive, transactive and transformative orientations' education.

The transmissive orientation treats knowledge as fixed and objective, determined by authoritative academic experts, codified in approved textbooks, and transmitted from teacher to student, as if pouring water into an empty vessel. Case (1998) argues that this view of education originates in *empiricist* views of knowledge, where all knowledge derives from sense perceptions, as in Locke's image of the mind as a *tabula rasa, blank slate*. Such an orientation is depicted critically by Freire's metaphor of transmissive teaching as *banking* or making a deposit of knowledge in the mind of a student (Freire, 2000, pp. 72–74).

Cummins' "traditional pedagogy" largely corresponds to Miller and Seller's transmissive orientation, while further elaborating on the approach within this orientation towards language, which he argues is treated as "decomposed" (2001, p. 255), that is, of discrete elements such as words, phrases, clauses and sentences that are treated atomistically and taught and learned in a decontextualized manner where elements of language are abstracted from content, context and communicative purpose.

Students in this mode play an essentially passive role merely receiving the knowledge as presented by an authority, the teacher. This orientation is typical of traditional pedagogy, in which knowledge is conceived of as unchanging "inert", and objective, that is, the same for all and not influenced by context and the perspectives of those who define, transmit or receive curricular knowledge. Cummins argues that this orientation leads to "sanitization" of the curriculum, so that it reflects knowledge perspectives of dominant sectors of society, and ignores social diversity, and complexity and the acknowledgement of power differentials in society are excluded. Cummins argues that such view of curriculum and pedagogy leads to "compliant and uncritical" students (2001, pp. 153–155).

The transactive orientation treats knowledge as something that may perhaps be objective, but that cannot effectively be transmitted to passive recipients. Teaching and learning in this view are accomplished through interaction, between learners and the world. Case (1998) argues that this view of education originates in *rationalist* views of knowledge, where the mind categorizes sense perceptions and phenomena according to apriori categories or innate knowledge. In post-positivist views of science, knowledge and truth, truth may objectively exist, but we do not have absolute knowledge of it; our theories are progressive approximations to truth. The process of hypothesizing, testing hypotheses and emending them in the light of empirical evidence continues endlessly. Knowledge in this orientation may be fixed, but is not simply given; if arriving at knowledge is seen as arriving at a destination, in the transmissive mode students are driven to the destination by teachers, whereas in the transactive mode, students are given a goal, a map and a vehicle, and the teacher is ever ready to pull them out of the ditch if they should get off track. Thus, the goal of learners is not creating knowledge, but *re*creating knowledge which corresponds to that of the teacher. The process of participating in knowledge creation is seen as making learning more meaningful to the learner and more long-lasting.

Cummins' "progressive pedagogy" largely corresponds to Miller and Seller's transactive orientation, while adding that progressive pedagogy takes a "whole language" approach, in which language learning is embodied within a meaningful context with a communicative purpose. He further argues that the view of knowledge in progressive pedagogy is a dynamic one with knowledge having a "catalytic" role in learning, with new knowledge stimulating inquiry which leads on to the discovery of further knowledge. Cummins argues that this orientation acknowledges and even "celebrates" a certain degree of social and cultural diversity, and promotes tolerance for diversity, and through dialogic relation between students produces a reduced power differential between teacher and student, but nonetheless continues the transmissive mode's exclusion from the curriculum of power differentials in society outside school. Thus, progressive curricula are also monocultural and promote "liberal, but uncritical" students (Cummins, 2001, pp. 154–157).

The transformative orientation treats knowledge as something that is not objective but subjective; it is not only arrived at through interaction, as in the transactive orientation, but is in some respects created by humans socially, for human purposes. In this view, there are multiple truths or at perspectives on truth. What is seen as knowledge is determined by values, purposes and power. Teaching then can be seen as giving to students, not objective knowledge, but the understanding that knowledge is not fixed and can be changed and that they can construct knowledge themselves for their own purposes and need not have their knowledge determined by others for purposes not chosen by the learners. Knowledge has the purpose here of emancipation of learners from external control (Miller & Seller, 1990). Case (1998) argues that this view of education originates in *sociohistoricist* views of knowledge, where all knowledge derives from mutual reactions to and actions upon the world.

Transformational approaches resemble transactive approaches in their approach to knowledge learning and language, but are distinguished largely by their assumptions about society and the inclusion of critical approach to learning in which students are empowered to think critically through relating the curriculum to the individual and group experience of students and to social realities outside the classroom. For students from non-dominant groups, Cummins argues, such a critical approach to curricula and pedagogy is necessary for students to be able to challenge and transform their non-dominant position in society (Cummins, 2001, pp. 154, 157–158).

Communication Within Transformational Education

Most school education, in Freire's view, treats the learner as an object, with the teacher acting as a subject, who determines what knowledge is significant for the learner and "deposits" this knowledge in the learner's mind, much as one deposits money in a bank. Freire notes that true communication does not exist in this model of education, since the teacher narrates what she/he wishes and all the learner can do is listen (or not). In this banking model of education, the content of the curriculum is selected without taking the learner's knowledge or interests into account and is thus alien to the learner: at best, making it difficult to learn, and at worst, making the passive acquisition of such knowledge counter to the learner's actual interests (2000, pp. 71–76). Freire opposes to this traditional "banking" education, education which truly involves communication:

> Yet only through communication can human life hold meaning. The teacher's thinking is authenticated only by the authenticity of the students' thinking. The teacher cannot think for her students, nor can she impose her thought on them. Authentic thinking, thinking that is concerned with *reality*, does not take place in ivory-tower isolation, but only in communication. (p. 77)

Freire argues that the aim of education is liberation, but that transmissive methods cannot lead to liberation, since they treat the learner as an object not a free subject. Rather, education that is not miseducation or indoctrination must treat learners "as conscious beings, and consciousness as consciousness intent upon the world". Freire's alternative to *banking* education is "problem-posing" education that takes into account that human beings exhibit "intentionality" and which embodies communication through dialogue between teacher and students (pp. 79–80).

It should be noted that the transformative approach to curriculum development presupposes no predetermined view of the content of the curriculum since it is established in dialogue between teacher and students and among students and thus cannot be completely fixed in advance. It is further significant that in Freire's conception of curriculum and pedagogy the dichotomy between centralized national and local curriculum is transformed, since the centralized knowledge cannot enter the pedagogic process except in dialogue with the learners and their current knowledge and interests which are largely based on local knowledge; thus, external knowledge must be integrated with knowledge and interests of learners, whether explicitly via the delivered curriculum or implicitly through the received, hidden and null curriculum.

Minority Education, Transmission, Transaction and Transformation

In multicultural, multiethnic states with centralized national curricula with a transmission orientation, there is a necessary conflict between the curricula desired by non-dominant cultural minorities and those promoted by central authorities. For central authorities who define knowledge in absolute, static and universal terms, there is no place for minority culture's "local" knowledge, which from their perspective does not constitute true knowledge at all, but is rather anachronistic, or backward, reflecting mere opinion and prejudice, or even worse, superstition. It should further be noted that Freire's approach assumes a certain independence of the teacher in the process, who in relation to academic specialists and department of education curriculum makers may also be treated, like students, as an object in relation to knowledge.

Freire's framework for understanding curriculum and pedagogy allows us to analyse differing approaches to minority education, for example in China, according to the degree to which learners and cultural communities are involved in curriculum development, by deriving curriculum from learners' current knowledge, interests and needs, and in curriculum enactment, involving them in a dialogic pedagogy in which their response to the curriculum influences the teacher's pedagogical choices which further influence students' responses.

It should be noted that minority cultures do not necessarily disagree with the transmission orientation to knowledge; rather, they may disagree on what content is worthy of transmission. Thus, while the transformative orientation to curriculum is most open to inclusion of content derived from non-dominant cultures within the curriculum, where the traditional approaches to knowledge, authority and teaching the young are also transmissive, there may be difficulties in applying transformative approaches to greater participation of minority communities in curriculum development.

Bernstein's Classification and Framing

Freire's framework itself takes a strong value orientation towards curriculum determination; Bernstein, on the other hand, proposes an approach towards curriculum analysis that is more descriptive than evaluative. Bernstein terms separation between the different elements of the curriculum "classification" and the level of restriction the curriculum imposes on the teacher and students in selecting what is to be learned within a lesson as "framing". Curricula with strict classification between subjects and high framing restricting teachers' and students' choices are termed by Bernstein as "collection codes", whereas for the opposite orientation, with weak classification between subjects and weak framing permitting broad student and teacher choice, he termed it as "integrated codes" (Bernstein, 1971, 1996).

Bernstein's categories may be used to bring out underlying attitudes towards authority and knowledge: where framing is weak, teacher's authority is higher and the authority of academic experts is lower; where classification is strong, knowledge derives from separate academic disciplines: knowledge from different domains is not integrated. Bernstein's framework resembles Freire's opposition of banking to non-banking education, but differs in that it does not explicitly value one orientation over another. It further has the advantage of having applications to different levels of the curriculum; for example, most current North American secondary school curricula exhibit a collection code with high classification between subjects and high restriction of student and teacher choice of what is included in lessons, yet primary school curricula exhibit a more integrated code, since classroom teachers teach all subjects, and may integrate lessons from diverse sources together, and have much control over what they teach, how and when, as long as they meet basic general objectives. Another application of Bernstein's framework is to classification and framing of schools and courses with strong classification between schools, where streaming exists between schools that specialize by type of course material.

The Challenge of Placing the Arts at the Core of the Curriculum

The place of the arts in education is increasingly recognized, with arguments for their importance coming from such diverse sources as psychologist Howard Gardner's *multiple intelligences* (2006) and curriculum specialist Elliott Eisner's work on the arts, cognition and *educational connoisseurship* (2002, 2017). They argue that including arts in education is a corrective to an excessively narrow focus on intellectual training in mathematics, literacy and science. Such work suggests that children have different initial strengths and weaknesses upon arrival in school and that to favour some areas of competence also favours some children, while neglecting strengths in areas besides numeracy and literacy.

So why would the suggestion of emphasis on equal importance in quality education of the arts, not to mention the social sciences, be so controversial in theory, difficult to enact in policy, and even harder to implement at the grassroots, school and classroom level? Neglect of the arts in education can be critiqued on *intrinsic* and *extrinsic* grounds: on the intrinsic side, a lack of arts-based approaches neglects development of significant aspects of what it means to be fully human; on the extrinsic side, many argue that inclusion and even integration in the curriculum of multiple disciplines and fields of knowledge, including the arts, also strengthens learning in literacy, numeracy and sciences. These arguments support general provision of arts-based education for all. However, authors such as Anyon (1980) have shown that the implemented and received curriculum is not the same for all, while Gladwell's (2008) recent discussion of the arbitrary effect of birthdate on entry into professional sport has brought to popular attention how differential treatment based on minor initial differences can exacerbate gaps between individuals and groups. Thus, if it is true that arts-based education is both generally beneficial, but provided differentially, seen as enrichment for some, and as a costly diversion from the basics for others, then, like the arbitrary age cut-offs in youth sports, exclusion from the arts may equally arbitrarily limit and impoverish the education of already marginalized students.

The question remains how to change inadequate curricular and pedagogical models. Recent history has privileged STEM subjects within the curriculum, so that arts, humanities and social sciences are often seen as relatively inessential. At the same time, Bernstein's classification shows how powerful and resistant to change curricular boundaries can be, while his notion of framing shows how weak individual teachers can be at particular times and places and disempowered to make educational decisions by themselves for the good of their students. Grant's comment also suggests a tendency to inertia on the part of some teachers to accept what more or less worked for them. As one US high school teacher said:

> The kid is where the problem is today. There is nothing wrong with the curriculum. If I could just get people that wanted to learn, then I could teach and everything would be wonderful. (McLaughlin & Talbert, 2001, p. 13)

Yet there is some consensus among researchers that quality education should reflect the diverse knowledge and cultural perspectives of the stakeholders involved. Chapman and Carrier (1990) argue that each culture has symbols that strongly influence perceptions of quality of education among local stakeholders, but that "when innovations in the school may diminish or eliminate these symbols, the worth of the total innovation may be questioned" (p. 13). Indeed, they conclude that judgments of educational quality must involve local stakeholders:

> The worth of an educational program is based not only on the perceptions of those who fund or administer the program, but on those who participate in it on a day-to-day basis, those who send their children to engage in it, and those who live with the program in their communities long after the program originators have moved on. (p. 14)

The World Bank (1995) has defined quality in education in developing countries as based on national mean achievement scores, but still claimed that local participation strongly affected quality:

> School governing bodies, principals, and teachers with their intimate knowledge of local conditions, are best able to select the most appropriate package of inputs. Under the right circumstances, making schools and higher education institutions accountable to parents, communities, and students helps bring about more effective learning and hence improves educational quality. (1995, p. 8)

The World Bank (1999) argued that criteria for quality must be decided with partners, with "the knowledge and understanding of local values, culture and traditions that are an essential feature of sustainable development" (p. 16), who include local communities, parents and students, whose participation in school activities and governance is "crucial" for quality education (p. 18).

UNESCO's Millennium Development Goals for Development defines quality in worldwide education in purely quantitative terms as the achievement by 2015 of universal primary education and the elimination of gender disparities between 2005 and 2015 (UNESCO, 2004, p. 28). UNESCO has also defined educational quality as "learning the right things to lead a decent life in a fast-changing world" for "future adult roles as creative, thinking citizens who can sustain themselves and contribute to the well-being of their families, communities and societies" (Pigozzi, 2006, p. 40), without specifying who decides what a "decent life" consists of. UNESCO (2004) also argues that quality requires relevance of education:

> imported or inherited curricula have often been judged insufficiently sensitive to the local context and to learners' socio-cultural circumstances. The Convention on the Rights of the Child stresses a child-centred approach to teaching and learning. This in turn emphasizes the importance of curricula that as far as possible respond to the needs and priorities of the learners, their families and communities. (p. 31)

UNESCO (2004) presents behaviourist, humanist, critical and indigenous views on quality in education (pp. 33–35), arguing that achieving quality requires dialogue among proponents of all four perspectives with the aim of establishing broad agreement on aims, objectives and the agreed upon dimensions of quality in education (p. 36).

A UNICEF publication defined quality in basic education as making "people's needs and well-being—the fulfillment of each person's human potential in its material, spiritual, individual, and social dimensions—the central focus" (Ahmed, 1991, p. 4), which requires national, subnational and local levels of curriculum authority allowing basic education programmes to adapt to the diversity of places and students. This would involve "major decentralization with greatly enhanced local responsibility and popular involvement" (pp. 10, 13) and the legal empowerment of "village education committees, … voluntary associations, social activists, and higher levels of government … to serve as countervailing forces to entrenched local structures of domination and exploitation" (pp. 14–15). In Ahmed's view:

> The process and inputs of education –how teaching-learning occurs, who teaches with what learning materials, and in what kind of facilities - are usually raised as quality related questions. These are appropriate and important questions, but these can be answered adequately only in relation to the goals to be achieved. It is, after all, possible to move with great efficiency and speed towards the wrong destination. (p. 73)

UNESCO, UNICEF and World Bank views are consonant with a strong form of school-based curriculum development (SCBD) (Marsh, Day, Hannay, & McCutcheon, 1990; OECD, 1979) in which principals and teachers making school curriculum, with students (Skilbeck, 1984), "parents and other citizens" (Marsh et al., 1990, p. 199), or "the parties involved in daily school work: teachers, parents, pupils, and school administrators" (OECD, 1979, p. 11).

How and why parents and students may resist teachers' objectives and what their perspectives on quality of education are, is under-researched within school effectiveness literature, although ethnographies of education of non-dominant groups have begun this task (Corbett, 2007). Despite research support for stakeholder cooperation, dialogue between teachers and other local stakeholders is relatively limited (Hargreaves, 1994; Lortie, 1975). Bryk and Schneider (2002) attribute such isolation to insufficient trust. Trust is common; they argue, in schools with little diversity, where cultural values and expectations about education are shared. Where there are few shared assumptions, trust must be established through dialogue, a challenging task when teachers' and parents' cultural and linguistic backgrounds differ widely:

> Teachers often see (poor) parents' goals as impediments to students' academic accomplishments. Parents in turn believe that teachers are antagonistic toward them and fail to appreciate the actual conditions that shape their children's lives (Bryk & Schneider, 2002, p. 6).

From Language Blindness to a New Appreciation of the Role of Language in the Realization of Educational Rights for Non-dominant Groups

Empiricist approaches to knowledge and education are often silent on the significance of language. Indeed, it is arguable that there is a "language blindness" within mainstream Western societies (Clyne, 2005), and also many academic fields, not only education research, where the role of language is not only not problematized but barely raised at all (Bahry, 2016). While no naïve empiricist, Dewey also does not directly speak of the role of language and literacy practices, but his notion of quality education depending on continuity of experience and *interaction*, the balanced interplay between external and internal factors of experience (1938) suggests an implicit place for language in his theory of experience. More explicit theorization comes from Gadamer (1976), who argues that rather than a simple instrument for use, language "always already" places us within horizons of meaning, and from Taylor (1982, 1995, 2016) who argues that meaning is not designative but expressive and that language practices are constitutive of identity. Gee posits several sources of identity involving linguistic mediation, especially Discourse Identity and Institutional Identity, achieved via primary or secondary discourses (2000–2001, 2012), while Cummins (2001) draws attention to discontinuities of language, identity and power faced by minority students in school, and the empowering/disempowering effect on student identities of how or whether teachers negotiate these discontinuities with students. All of these theorists see language as necessarily involved in meaningful human experience, some implicitly, some explicitly making transcendental arguments (Taylor, 1995, pp. 20–33) about the "conditions of possibility" (Bourdieu, 1990, p. 95) of human endeavour, including linguistic practices. Thus, quality education seems to require language, at a minimum, as a medium of interaction in transactive approaches to learning, or more, as a dynamic, constitutive, expressive element of transformative practices.

How does this link to rights in education, even more so to linguistic rights in education? Dewey's continuity of experience seems to require linguistically mediated interaction between internal and external aspects of experience: students' prior knowledge, culture, interests and language practices and teacher's knowledge, culture, interests and language practices. Where imbalance between internal and external aspects is great and, more importantly, linguistic gaps between teacher and student are too great to overcome, miseducation occurs. The Paideia Proposal (Adler, 1982), for example, follows extremely closely many of the suggestions raised in this volume about the need for all types of learners to be exposed to an enrichment education which includes acquisition of organized knowledge in three domains: language, literature and the fine arts; mathematics and natural science; and history, geography and social studies; and the development of intellectual skills, including problem-solving and critical judgement, 3) enlargement of understanding of ideas and values through coaching and supervised practice, and 3) Socratic questioning and active participation in discussion of books and works of art and involvement in interpretation, performance and creation of artistic works (p. 23).

Like the form of STEAM education advocated for in this volume, the Paideia Proposal insists on integration of arts with STEM subjects, awareness of literature and development of skills in language and so seems compatible with the current volume's argument for infusing STEAM with linguistic rights for speakers of non-dominant languages. The Paideia Program is also recommended for all, especially minority students, as necessary for democracy, and focuses on the common language, in this case, English, and learning a second language. Thus, despite its Deweyan inspiration (pp. 3–4, 52), falls short of Dewey's continuity of experience principle by making no commitment to extension of the Anglo-American liberal arts curriculum to include content from the cultures of non-dominant students and by not extending study of “modern” languages learning to include study of, and even learning in the language(s) of all students, their families and their communities. If genuine education (not training, indoctrination, non- or miseducation) is a right, as it certainly is under several United Nations conventions, and a condition of possibility of enjoying that educational right is active communicative use of student and community languages, clearly the use of these languages is also a right. Thus, the current volume plays a salutary role in arguing for a conception of STEAM education intended to ensure breadth and continuity of experience, thus genuine education for members of non-dominant groups, a significant step towards Quality Education for All.

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The Ubiquity of Arts in Knowledge

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The English *art* derives from Ancient Latin *ars/artis,* which corresponds to the Ancient Greek *technē,* which can be translated into modern English as well by *craft* as *art*. This reminds us that art involved practical knowledge and reason applied in making of objects for human use by artisans/craftspersons. Thus, the arts provided much of the subject matter for science when those with leisure went beyond practical knowledge of *what and how things* could be made to inquire more abstractly into *why* things were as they were.

Art, at its core, is an origin for science, technology, engineering and mathematics. There is a thin line between how we come to *know* and *accept* history, traditions and practices. This knowledge comes from the retelling of narratives we adopt to present to other generations as a foundation to move forward. Art, through the mediums of literature, imagery, texture, voice and movement, continues to inform us of our surroundings and ourselves. Identifying science, technology, engineering and mathematics collectively as a newly conceptualized formula has been embraced by academics in the twenty-first century to popularize an acronym representing several additional foundations of knowledge combined as the new frontier of what art has represented for centuries. Yet, just over the past 20 years, we are presented with a moment to review our collective histories and to move yet again towards defining these branches of knowledge to dissolve the invisible barrier between art and STEM.

To do so, it is imperative to acknowledge that just because a border is *invisible* does not mean that it is without consequence. Dr. Babaci-Wilhite will require of all who review the work gathered here to consider how problematic, artificial are the external and internal boundaries of STEM to again raise the question of the relation of STEM to *Art*. With the invitation of global scholars contributing to a discussion of how linguistic rights and cultural diversity challenge what we know of the origin of STEAM, we are presented with the core question of what should be accepted. Though dated, discourses on the formation of what historically may be thought of and defined as STEAM in institutions of education present a closing of the circle to determine what is outside or borders its context, setting the stage for the work presented in this book.

Science, especially in (but not limited to) a Western education context, signals that which is *hard, definite, absolute and unchanging* while simultaneously being innovative and evolving. Art, on the other hand, though often labelled as being innovative and evolving, is at its core resistive to predictability and demands challenges to what seeks to define it.

The liberalization of STEAM narratives, particularly as to why they may exist, unearths for many in the field of linguistic rights and cultural identity pillars of indigenous, complex, multifaceted history. The richness of these narratives has been long known and in practice for many cultures without the need of academic discovery. This is a fact that Dr. Babaci-Wilhite and her co-authors are all too aware of. This compilation of studies draws from traditions as wide as medicine to music to illustrate how participatory models of engagement fashion pedagogical practices in STEAM. This makes for an invaluable opportunity to observe, learn and question how dialogical relationships with the global communities we serve and learn from provide access to knowledge.