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Contents

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Part I
Conceptual Views on Practices and Materiality in Education

Chapter 1
Introduction to Emergent Practices and Material Conditions in Learning and Teaching with Technologies

Teresa Cerratto Pargman and Isa Jahnke

Abstract This volume invites the reader to explore the complexities and the dynamic character of interacting with technologies that unfold in the everyday flow of practices in schools, museums, field trips, and the home. In particular, we paid attention to the material conditions of such practices via, for instance, the exploration of media discourses on information and communication technologies in the classroom; the ongoing digitization of the school; the use of video chat for language learning; the instantiation of CrossActionSpaces in urban science classrooms; the development of symbolic technologies such as the Carbon Footprint Calculator; the design of apps and virtual museums for learning science; the use of text message tools for collaborative learning in teacher education and the design, implementation, and evaluation of Augmented Reality (AR) apps in outdoor learning. As a result, this volume brings together inspirational and high-quality chapters that raise a range of important ideas and showcase the importance of looking *beyond* technology-enhanced learning. Five take-away messages are presented at the end of this chapter. They summarize how the chapters included in this volume contribute to understanding everyday practice and materiality as constitutive of human cognition, agency, educational values and creative critique. Taken together they call for complementary views of research on technologies in education and invite scholars in the field to reimagine studies about learning and teaching in the digital age.

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Departure Point: What Is Really Happening Versus What Is Expected to Happen with the Use of Digital Technologies for Learning and Teaching

This book is the fruit of a continued collaboration that started almost 5 years ago, when Isa and Teresa first met in person during a doctoral thesis defense in 2014 in Stockholm. It was during this first meeting that we realized that we were both conducting research projects with similar aims, namely, exploring how Nordic schools were integrating mobile devices and services into the classroom without any technologically driven intervention from the research side. During these first conversations, we quickly and pleasantly understood that we were sharing a set of research insights vis-à-vis research at the intersection of education and technology.

This shared understanding worked as a common ground that inspired a stimulating intellectual journey that commenced with the organization of two very successful workshops at the biannual Computer Supported Collaborative Learning conference (CSCL). One of the workshops was held at CSCL 2015 in Gothenburg, Sweden (Jahnke, Cerratto Pargman, Furberg, Järvelä, & Wasson, 2015), and the other workshop was held at CSCL 2017 in Philadelphia, in the USA (Cerratto Pargman, Jahnke, Damşa, Nussbaum, & Säljö, 2017). The compelling studies presented by participants gave us insights that led to further vivid discussions. We all engaged discursively during these conference workshops and contributed to a rich understanding of the types of changes that mobile devices and services bring to school practices. The work that was discussed at these academic venues also helped us to engage with the material conditions of digital technologies that are enacted in emergent educational practices. Thus, the idea of collaborating and editing this volume grew out of a common wish, namely, contributing to an alternative narrative about the integration of digital technologies in schools.

For such an alternative narrative, we were looking for research studies that complemented the vast number of works focusing on learning efficiency (Roschelle, Penuel, Yarnall, Shechtman, & Tatar, 2005), motivation (Kim & Frick, 2011), knowledge acquisition, and inquiry-based learning. Unlike past research that has worked with design-oriented and research-oriented interventions in schools (Cerratto Pargman, Järvelä, & Milrad, 2012; Cerratto Pargman & Milrad, 2016; Eliasson, Cerratto Pargman, Nouri, Spikol, & Ramberg, 2011; Eliasson et al., 2012; Eliasson, Knutsson, Ramberg, & Cerratto Pargman, 2013; Jahnke, Bergström, Mårell-Olsson, Häll, & Kumar, 2017; Jahnke & Kumar, 2014; Nouri, Cerrato-Pargman, & Zetali, 2013), we aimed to identify, and explain how teachers and school principals take *command* of the digitalization of schools and, by doing so, engage in the development of new teaching and school practices. This interest was concomitant with a change perceived at the level of school principals' and teachers' attitudes towards technology in the classroom; such a change was particularly reflected in the teachers' entrepreneurship, commitment, and willingness to make mobile devices work in the everyday life of the classroom. What followed from this was a necessity to thoroughly describe what was really happening during the appropriation of mobile devices in school activities and how the results deviated eventually from the initial research goals of studying what was expected to happen (e.g., learning efficiency).

During the collection of studies for this volume, we shared the belief that the integration and use of digital technologies in schools has most often been studied as separate from established teaching and everyday learning practices (Cerratto Pargman et al., 2017; Cerratto Pargman, Knutsson, & Karlström, 2015; Hakkarainen et al., 2015; Nouri & Cerratto Pargman, 2016). It is still notable that studies most often conducted in our field do not take into consideration that digital technologies are not only tools but also communication and learning spaces that constitute and are constitutive of today's school practices (Jahnke, 2015). Furthermore, there is also a tendency to approach technologies in terms of the suitability of a specific tool for serving a predefined learning or teaching purpose. Sörensen (2009) underscored that researchers in education often tend to

> first consider how children learn and develop and what characterizes good interaction, and only after that they ask how technology can be applied to create these conditions. Researchers rarely consider that it may be the other way around: that we theorize about learning the way we do because we have certain learning materials in mind when we account for learning. (p. 7)

Sörensen's observation resonates with our interest in exploring the multiple relations that are established, maintained, and reproduced when using technologies in schools, as well as with our desire to examine conceptual tools that are able to help us grasp the nuances and complexities inherent to appropriating digital technologies in everyday schools practices.

Focus: Relationships Among Emergent Practices and Material Conditions

The choice of the topic of this edited volume is grounded in a profound interest in the relationships that develop among tools, technology, and learning (Säljö, 2010). Within these relationships, we understand that learning gains materiality through the use of tools and, consequently, such materiality has implications for learning, as it potentially transforms "how we teach and learn as well as how we come to interpret learning" (Säljö, 2010, p. 53). Situating learning and teaching into the material world—that is, its physicality as well as its social organization—causes us to view these activities as embedded within sociocultural activities that are bound to tools that make them possible (Rabardel, 1995; Säljö, 2010). This interest in the overlap among material, cognitive, cultural, and social aspects of teaching and learning has recently been renewed in works that specifically take a socio-material lens on learning (Fenwick, Edwards, & Sawchuk, 2011; Johri & Olds, 2011; Sörensen, 2009).

Such a lens addresses the degree to which social and material facets that are involved in contemporary forms of learning are intertwined. It studies, on the one hand, the use of technologies in educational settings and, in particular, how technologies take part in the practices in question (Sörensen, 2009). On the other hand, a perspective on the socio-material conditions in education also engages with the specificities of the technology at hand, that is, its materiality, which becomes tangible through both the constraints and affordances that emerge for the user during use (Kaptelinin & Nardi, 2006; Rabardel, 1995). In an effort to explain how this book brings educational practices and material conditions together, we describe more precisely what we understand from them and why we believe both have a natural place in studies about technologies in education.

Everyday Practice as the Unit of Analysis

The choice of everyday practice for studying the use of digital technologies in education responds to the necessity to find both an accurate and a macroscopic unit of analysis able to embrace the complexity and dynamic character of everyday teaching and learning with digital technologies. More importantly, this choice responds to the ambition to investigate prevailing discourses on educational technologies from the everyday realities experienced by the teachers and the learners in their educational contexts.

Our understanding of practice is grounded in the work conducted by Lave (1988), Wenger (1998), and Engeström (2001) in the field of education, the work of Schatzki, Knorr Cetina, and Savigny (2011) in the social sciences, and the work of Kuutti and Bannon (2014) in the field of human–computer interaction. Using these works as a conceptual basis, we approach everyday educational practice as embodied, collective action—coherent social activity developed over time and underpinned by specific values that give structure and meaning to what we do. As Barnes (2005) expressed, "practices are socially recognized forms of activity, done on the basis of what members learn from others, and capable of being done well or badly, correct or incorrectly" (p. 19).

Engaging with everyday practice in studies of technology in the educational context means engaging not only with individuals but also with what groups and communities do in their everyday lives, as people enact practices via their actions and activities (Wenger, 1998). Studying the practices also means engaging with an array of tools, resources, documents, regulations, and spaces that make possible everyday practices in such specific communities. It also entails inquiring as to the design of technologies, which always reflect understandings of the specific practices they aim to facilitate through the functionalities and interfaces they offer. Sites such as schools, museums, learning centres, or the home can thus be viewed as communities of practices where particular artefacts partake in and shape the sociocultural practices in which individuals operate (Lave, 1988; O'Malley, Suthers, Reimann, & Dimitracopoulou, 2009; Stahl & Hesse, 2009; Wenger, 1998). In this context, the concept of practice helps us to critically revise the idea of "educational technology" as a given objective facticity (Jahnke, 2015), disembodied from designers' and institutional design practices, knowledge, and values. Engaging with the practices that are reflected in the design of educational technology makes it possible to understand that the design of technologies is not neutral or objective, and certainly not apolitical, as we would like to believe. As Stommel (2014) alerted us, every technology embodies specific values in its design that are enacted when the technology is put into use. On this note, Haas (1996) underscored that

> Not only do groups develop technologies with cultural assumptions and power relations in place that guide development efforts, but people also construct certain uses and purposes for technology through discourse that is itself, in turn, shaped in profound ways by cultural beliefs about technology. (p. 227)

It is here—at the intersection of educational practices with design of digital technologies and discourses about educational technologies—that we now turn our attention to the study of material conditions that is central to this volume.

Understanding Material Conditions

Engaging with the material conditions of educational practices means paying attention not just to the material or thing but also to the multiple relationships or mediations that are afforded by and constrained in the interactions among teachers, learners, and school materials (e.g., artefacts, strategy documents, policies). It also entails grasping the educational values and ideologies that are embedded in the design of digital technologies and such artefacts. Following Sörensen (2009), material conditions of educational practices also invoke the relational character of materiality. Here we speak of a materiality that is distributed between social and physical processes. In this regard, material conditions are not only consolidated in artefacts but also are distributed in relationships between people and things.

The intention behind the idea of bringing material conditions into the fore is to acknowledge, discuss, and reflect on the mutual configuration between everyday educational practices, the educational materials that are in use and the discourses on technologies in education. On this note, Culkin (1967) in his schoolman's guide to Marshall McLuhan illustrated well the overlap between designed materials and practices when he spoke about the entanglement between humans and their tools: "We shape our tools and thereafter they shape us" (p. 53).

The theme of material conditions in education has, as Lindwall, Häkkinen, Koschmann, Tchounikine, and Ludvigsen (2015) noticed, already been explored in numerous ways, including, but not limited to

> basic research of collaboration, learning processes, knowledge formation, and media ecology; applied research and design studies of how specific tools, applications, and activities are used and modified for the benefit of relevant fields of practice; and theoretical approaches to the development of the interdisciplinary fields of CSCL and the learning sciences and their manifestations in society. (p. iv)

Yet, studies seeking to engage with the materiality of learning and education in the digital age are often peripheral in our field. This is surprising for at least two reasons.

First, as Fenwick et al. (2011) alerted us, "practice that is doing, is not ontologically separable from learning and human development but is the very substance of it. However, what is material is often taken to be the background context against which educational practice takes place or within which it sits and material artifacts are often taken to be simply tools that humans use or objects they investigate" (p. 1).

Second, information and communications technologies (ICTs) are both material and cultural tools that "impinge on cognitive activity and constitute each other" (Haas, 1996, p. 46). Haas illustrated this point in her distinction of the two myths about digital technologies that often impede explicitly looking at the material conditions of the practices bound to technologies. On the one hand, she spoke of technology understood as a transparent medium and, on the other hand, as technology linked to a sort of supremacy over other human activity. The myth associated with the transparent character of technology presupposes that technology is a means for ensuring learners' and teachers' efficiency and performance without making any profound difference in how learning or teaching is conducted. Such a view becomes tangible in accounts emphasizing the introduction of technology in education as a "win." Such a view conveys the implicit understanding that technology is immaterial, and, as a consequence of its nature, one could easily understand that there is little need to study it at all. The counterpart of the transparency myth of technology is the myth that presents technology as all-powerful and self-determining, meaning that it will have profound and essentially one-way effects on activities (Haas, 1996). This myth proclaims technology as something that is unique, active, and an independent agent of change, determining its own uses and effects and, as such, communicating that studies wanting to engage with the materiality of technologies are obsolete (Haas, 1996). These myths are explanatory of why it is at times hard to engage with the study of the material conditions of learning and education.

This volume seeks to challenge assumptions that are implicitly made in these myths and that underpin much of the work we know about technologies in education. This task is, needless to say, not an easy one. The accelerating pace of technological innovation challenges us to construe sensible and sensitive accounts of how digital materials are altering established educational practices as well as established understandings of learning and teaching. Likewise, the accepted conceptual and methodological tools that we have at hand sometimes fall short in describing and explaining the complexities and intricacies that are inherent to the dynamic character of teaching and learning with digital technologies.

In this respect, the studies and examples in this volume argue for the study of the material conditions of learning and teaching with digital technologies, as they are constitutive of contemporary educational practices.

Organization of This Edited Volume

This volume gathers a collection of 16 high-quality scholarly contributions that address a range of concerns and perspectives. By way of empirical studies conducted in Europe, North America, and South America, these chapters showcase a variety of situations, design interventions, concepts, and methods for the study of digital technologies in school classrooms, museums, outdoor learning centres, and the home. Taking a perspective on everyday educational practices, the volume offers a variety of contributions that critically describe and conceptualize social and material conditions constituting learning and teaching in the digital age.

This volume is organized in four parts.

Part I: Conceptual Views on Practices and Materiality in Education

Part I introduces the conceptual views that explain the meaning and relations among the concepts of materiality, cognition, and practices in teaching and learning with technology. In Chap. 1, this chapter, the editors tell the story behind this book as well as the goals with the volume.

In Chap. 2, Roger Säljö introduces "Materiality, Learning, and Cognitive Practices: Artifacts as Instruments of Thinking." He develops the argument that technologies in and of themselves are products of learning and that they are not just representations of the world but rather are constitutive elements of our intellectual abilities. Putting the emphasis on materiality as a constitutive element of cognition, Säljö explains via the example of the Carbon Footprint Calculator that this technology does far more than calculate: it is a conceptual tool that structures a problem in ways that are relevant for learning and for participation in contemporary society.

Chapter 3, written by Teresa Cerratto Pargman, "Unpacking Emergent Teaching Practices with Digital Technology," challenges us to study the digitalization of schools from the point of view of everyday teaching practices. Cerratto Pargman unpacks teaching practices in terms of materials, competence, and meaning, as well as their relationships, via the analysis of experiential qualities. The findings lead her to discuss the teachers' experimental practice with digital materials, as well as the emerging managerial communication in elementary schools. The chapter contributes to a discussion of the tensions between incremental and radical changes in teaching with digital technologies and offers an elaboration of the relevance of a lens on practice in studies about technology and education.

Chapter 4, written by Mariana Landau, "Exploring Representations of Classroom Practices Mediated by Information and Communication Technologies (ICTs)," provides a set of analytical dimensions that facilitate the scrutiny of the representations of classrooms mediated by ICTs in the written press in Argentina and Uruguay. In particular, Landau studies how the media/press photos present to the public how schools use digital technologies in their classrooms. The chapter contributes five issues that critically point to the problem of simplification of actual practices with ICTs in the schools.

Part II: Understanding Emergent School Practices and Their Inherent Materiality

Part II brings together a rich and compelling ensemble of case studies that were conducted in diverse educational contexts. In particular, they illustrate the varied ways of appropriating technologies and apps in the everyday classroom.

Chapter 5, written by Marcia Håkansson, "Conditions for Teaching with Mobile Technology in the School Classroom," engages with the analysis of the 1:1 laptop initiative—one device per student—in two Swedish schools. Håkansson investigated the conditions for teaching by adopting the Ecology of Resources Model as developed by Luckin. Her results show that teachers focused on helping students to view the laptop as an educational tool and not as a tool to play with. Her study also points out that teachers noted the importance of pedagogical reflection and design, but that they also faced technical challenges.

Chapter 6, written by Eva Mårell-Olsson, Peter Bergström, and Isa Jahnke, "Is the Tablet a Teacher or a Student Tool? Emergent Practices in Tablet-Based Classrooms," summarizes the authors' study of principals' and teachers' views in schools. They investigated teachers' designs of tablet classrooms and used the Activity Theory to analyze the teachers' motives, goals, actions, and operations. Their findings show how principals' leadership affects teachers' design: it affected the emergent practices of teachers' strategies for developing a teaching design that attempts to fulfill individual student needs. Teachers were struggling to provide customized education, and for some teachers, the tablet was a teacher tool (e.g., distribution of information, assignments), while for other teachers it became a student tool that enhanced student activities *with* and not *from* tablets (Jonassen, 1996).

Chapter 7, written by Jennifer D. Adams, "WhatsApp with Science? Emergent CrossActionSpaces for Communication and Collaboration Practices in an Urban Science Classroom," presents an in-depth case study of a teacher in an urban science classroom forming a CrossActionSpace. Adams introduces the notion of the critical agentic *bricoleur* to describe how the teacher used existing digital resources in new ways and that were resonant with the teacher's professional identity. By analyzing the classroom's discourse generated in WhatsApp (a messaging tool) to make sense of the unfolding social practices of science learning, Adams discusses how the agency developed in this CrossActionSpace is transcendent and creates the conditions for all participants to contribute to a learning culture of mutual trust, collaboration, and academic success.

In Chap. 8, "'Wow' and Then What? Tablets in a Conservative Polish School: Mapping Emergent Teaching and Learning Practices in the Classroom," Lucyna Kopciewicz and Hussein Bougsiaa report on observing 60 classrooms in primary schools. They applied video ethnography and conducted interviews with the classrooms' teachers. The results show conflicts and tensions that are constitutive of the teachers' experiences with the adoption of the tablet in their classrooms. The "wow" in the title of this chapter stresses the teachers' excitement, hope, and expectations that the tablets will work "wonders". The teachers perceived tablets as a magic wand, and they hoped they would cause radical changes in the classrooms, but as the authors stated, "However, nothing like that happened." By engaging with the teachers' disappointment as the teachers began to wonder "and then what?" the authors scrutinized the teachers' ways of integrating the tablet as a school tool in the everyday classroom.

In Chap. 9, "Material Conditions of Collaborative Knowledge Construction: The Case of Monoplant," Anders Mørch, Hani Murad, Jo Herstad, Sjur Seibt, and Morten Kjelling introduce us to Monoplant, a prototype educational construction kit that provides teachers and high school students with hands-on experience in plant biology. The material conditions of Monoplant provided students with an explorative design space for collaborative learning and real-life and physical experiences. Based on the analysis of observations, video recording, and interaction captured during the students' solving of a photosynthesis assignment, the authors suggest an emergent practice in which teachers need "makerspaces" for creating material conditions for students' domain-specific collaborative knowledge construction.

In Chap. 10, "Orchestrating Learning as an Emergent Practice in the Use of Location-Based Games with Mobile Devices," Jimmy Jaldemark, Sofia Eriksson Bergström, and Peter Mozelius describe the design of a place-based game that was based on the idea of Pokémon GO. The authors analyzed how teachers in middle schools adopted the gamified activity in educational practices in which teachers combined indoor and outdoor sessions. The results illustrate the emergent practice of orchestrating learning, mobile devices, and location-based games in which students and teachers act as co-designers. The chapter contributes to a better understanding of how orchestrations of educational settings may benefit from building links to everyday phenomena encountered by students.

Part III: Discerning Material Conditions in Informal, Outdoor Learning and Learning in the Wild

Part III presents inspirational work that puts the focus on the material conditions of practices that unfold in outdoor settings, museums and the home. .

Chapter 11, "The Impact of Materiality on the Design of Mobile, Augmented Reality Learning Environments in Non-formal, Outdoors Settings," written by Eleni Kyza and Georgios Georgiou, introduces the development of an AR technology called TraceReaders for a summer club for students mainly in the 11th grade. The study explores aspects of the socio-material perspective of location-based AR activities as these emerged from two iterations during an outdoor inquiry investigation. The contrast of the pedagogical practices during these iterations with practices in traditional schooling environments, which share the same epistemic goals, indicates that the unique characteristics of location-based AR investigations require a different design approach. This approach should account for the emergent interactions and the situated activity among the participants, the locality, and the technologies at play. The findings point to challenges of developing instructional design principles that consider aspects of materiality during learning with AR technologies in outdoor settings. The chapter invites us to further engage with evidence-based design frameworks that account for the socio-material interactions of all constituent components and that can create spaces for rich learning interactions.

Chapter 12, "Emergent Digital Multiliteracy Practices at the Core of a Museum–School Partnership," written by Stefania Savva, describes the design, implementation, and evaluation of a museum–school partnership that unfolded over 13 weeks of a student-generated virtual museum to support science, technology, engineering, and mathematics (STEM) curriculum for K–12 primary education in Cyprus. By analyzing the museum–school partnerships, Savva discusses an emergent multiliteracy practice in which students were engaged in the learning process as active designers and multimodal learners. In such a process, Savva argues that the students enacted repertoires of digital literacy that reflected critical thinking skills and higher-order thinking.

Chapter 13, written by Christian Waldmann and Kirk Sullivan, shows "How the Materiality of Mobile Video Chats Shapes Emergent Language Learning Practices in Early Childhood." In particular, the authors applied action research to study how the introduction of mobile video chats for children shapes learning a language and creates the material conditions for language engagement and participation practice, which, in turn, encourages language learning in additional contexts. The authors engaged with the material conditions of the mobile video chat not as a "black box" but rather as a constitutive aspect of social learning that may support participation and engagement.

Chapter 14, "Sociomaterial Configurations and Resources Supporting Observations in Outdoor Learning: Results from Multiple Iterations of the Tree Investigator Project," written by Heather Toomey Zimmerman and Susan M. Land, advances technologically enhanced outdoor science learning for out-of-school time with the Tree Investigator app. This app combines AR and digital photography to support families and children in their engagement with science practices related to trees. The authors describe how their theoretical framework shifted from dialogical to trialogical concepts to elucidate the socio-materiality of the scientific practices observed. The chapter contributes to a better understanding of the utility of broader theoretical frameworks and approaches to design that operate at the intersection of people, tools, and context.

Part IV: Moving Forward

Part IV shares thoughts that challenge us to reimagine studies about technologies in education.

Chapter 15, "Implications for deep learning.Unpacking the practice of teaching and learning with technologies" written by Isa Jahnke, adds compelling implications for deep learning that she identifies when taking a practice lens on the material conditions of learning and teaching with technologies. By using the approach of CrossActionSpaces, Jahnke provides an alternative view to the concept of teachers as workplace learners.

Chapter 16, "Next Steps: Toward a Relational Mode of Thinking for Educational Technology," written by Teresa Cerratto Pargman and Isa Jahnke, summarizes what we learned during this intellectually stimulating journey and suggests research issues to continue the work started here.

Take-Home Messages

The volume contributes a variety of compelling qualitative case studies that provide us with rich descriptions of what actually happens day to day in educational situations with digital technologies. In particular, such a contribution is reflected in the following take-home messages that emerge from the chapters constituting the present volume.

#1 Understanding Everyday Practice

Most of the current discourses about educational technologies are unfortunately dominated by promises and expectations of how technology *alone* can resolve issues that relate to quality education for all, learning enhancement, and societal growth. These optimist discourses are seldom grounded in the practices and realities inherent to daily educational life. This volume illustrates how research that focuses on educational practices can contribute to deconstructing such discourses with evidence from the field. Accounting for the struggles, tensions, material and human costs that the integration of technologies entails is necessary for the advancement of knowledge and further design of technologies.

For example, the work contributed by Landau (Chap. 4) illustrates well how the media narrow and simplify the realities of integrating ICTs in schools. For instance, she discusses scenes that most often show the student interacting alone with a computer and omit images showing students working together or with the teacher. These images narrow down the understanding of digital literacy development by reducing this understanding to an individual process. Landau also points to the prevalence of images showing classic elements of the school context such as the blackboard, the notebook, XO devices, and the absence of other more mundane elements such as cell phones, applications, programming, and robotics, which are also constitutive of emergent practices and material conditions in teaching and learning with ICTs. Of particular interest is Landau's observation pointing to the importance of distinguishing that the distribution of equipment made by the national policy is not necessarily the same made by the educational policy. These distinct types of initiatives are sometimes presented as one, both in governmental documents and in the media. Such a simplification hides the complexity that entails teaching and learning in new environments, reading and writing via the new media and semiotic modes, and capitalizing on the variety of legitimate knowledge sources that currently circulates at schools.

With a focus on teachers' everyday practices, the work conducted by Mårell, Bergström, and Jahnke (Chap. 6) unveils the specific strategies that teachers use for constructing a teaching design that attempts to fulfill each student's individual needs. Their study reports on how teachers struggle in providing a customized education for all. For some teachers, the mobile technology is appropriated as a teacher tool (e.g., for distribution of information and assignments), while for other teachers, it becomes a student tool that enhances student activities *with* and *not from* tablets. In a similar research project, Håkansson (Chap. 7) contributed to a case study on a 1:1 initiative conducted in Sweden (one device per student) that shows the teachers' efforts to combine pedagogy with mobile technology. The results show that teachers supported students in perceiving the laptop as a school tool and not as a tool to play with. Teachers noted the importance of pedagogical reflection, but they also faced technical challenges that created a hurdle for what they actually wanted to do. Håkansson's work clearly shows that the material conditions constituting the emergent teaching practices studied were highly underestimated. Emergent practices in the classroom are also a main focus in the study presented by Kopciewicz and Bougsiaa (Chap. 8). Here the authors account for the conflicts and tensions experienced by teachers using tablets in everyday classrooms. Their study vividly recounts the excitement, hope, and expectation experienced by the teachers with the presence of the tablets, and most importantly, the teachers viewed the tablets in the beginning as "magic wands" that would be able to radically transform teaching and learning (cf. Jahnke et al., 2014). Pointing to the teachers' disappointment, their work problematizes the idea of mobile technology as a self-determining, independent agent of change.

Inspired by Lave's seminal work on *Cognition in Practice* and works in the field of Science and Technology Studies, Cerratto Pargman (Chap. 3) argues for an approach of social practice for the study of technologies in education. Her work shares a set of conceptual tools that enable us to dive into the dynamics of everyday teaching in schools that are integrating digital technologies into educational practices.

These contributions clearly point to the need to turn to research on practice. In this sense, it is relevant—and perhaps even more important than ever—to note that with new technological developments, such as mixed-reality (XR) platforms, mixed spaces can be built and developed according to "reality," which can also support "fake" realities (Erdelez & Jahnke, 2018). Particularly in this context of technological innovation, it is necessary to relate to accounts of everyday practice so researchers can inform designers and developers of the dynamics of learning and teaching with technologies in the various milieus they unfold (Goggins, Jahnke, & Wulf, 2014). On this note, innovations, such as the ones provided by the spatial explorations of users in augmented or social virtual reality, will become the message for the learners (Culkin, 1967). In this regard, it is important to ask this: how will teachers, instructors, and learners make sense of these new socio-technical arrangements for their learning, training, and teaching? How will such arrangements shape relationships between the participants, and how will participants shape their learning? How will participants gain agency in new emerging CrossActionSpaces (Jahnke, 2015)? These questions speak about the pertinence and necessity of discussing everyday practice as the unit of analysis for the study of technologies in education.

#2 Materiality Is Constitutive of Cognition

Many of the contributions in this volume speak to the overlap of materiality and cognition. In particular, Säljö, in Chap. 2, alerts that "the engagement with material objects has always served as a trigger of human thought and conceptual development. It is by externalizing ideas and attempting to implement them in physical form that human conceptual resources have expanded." (Säljö, Chap. 2). The point that Säljö makes here is that when studying and theorizing about material conditions of learning and teaching with technologies, we need to scrutinize how material and conceptual entities, that have been configured through history, are implemented in artifacts. Artifacts such as symbolic technologies "are not just representations of the world, rather they are constitutive elements of the enactment of thinking and reasoning in social practices where they serve as powerful "cognitive amplifiers". From this perspective, it becomes clear that "artefacts and cognition are intertwined in a distributed and constantly evolving system of thinking and symbolic technologies by means of which human reasoning is enacted in practices" (Säljö, Chap. 2).

In light of this conceptual understanding of materiality as constitutive of human cognition, Mørch and colleagues (Chap. 9) describe the case study of Monoplant, a plant biology application. The authors investigate this: what material conditions of collaborative knowledge construction does Monoplant bring to the foreground? Putting the focus on students to solve a photosynthesis assignment requiring them to compare the growth of two plants, Mørch and colleagues showed the involvement of physical tools, visual representations, and materials during the learning process. In particular, these material conditions provided an explorative design space for students' collaborative learning. Furthermore, the authors found the need for maker spaces to create material conditions for domain-specific collaborative knowledge construction.

Regarding how materiality is constitutive of students' multiliteracy, the case study presented by Savva (Chap. 12) shows how students engaged in designing their own virtual museum enacted repertoires of digital multiliteracy that reflected critical-thinking competences and higher-order thinking. Another compelling example is Toomey Zimmerman and Land's study (Chap. 14) that shows how an iterative design process made them shift their focus from placed-based education (with an original focus on learning in community spaces) to socio-material perspectives, with a focus on place as well as people's bodies, tools, and material resources. Their shift of focus provided learners and families with better support for learning of biological concepts via sense making and connecting speech. In this line of reasoning, Kyza and Georgiou (Chap. 11) present the development of an AR technology called TraceReaders for students mainly in the 11th grade in a summer club. Their work argues that designing for "optimal" learning should raise awareness of the relations among humans, technology, and the environment, that is, the need to carefully consider characteristics of the participants; the affordances of the AR technologies, which are bounded by the material conditions; and the nature and goals of the learning activity. The work presented by Waldmann and Sullivan (Chap. 13) focalized language-learning practices of two bilingual children living in Sweden. Waldmann and Sullivan found that the material conditions of mobile video chats, such as portability, multimodality, and access to situated and personalized experiences create opportunities, allowing an emergent language-learning practice to develop in the home. Furthermore, such materiality of language learning provided the children with opportunities for engaging and participating in authentic language practices.

#3 Exploring Agency

Several authors in this volume point directly or indirectly to the need to engage deeper with students' and materials' agency in teaching and learning with digital technologies. For instance, Adams (Chap. 7) illustrates how agency is not a fixed end point but rather is a constantly evolving entity, as teachers and learners engage in social practices and spaces differently. For science teachers, materials are central to creating effective learning environments. Yet, for those teachers who are teaching science in spaces that are resource challenged, agency also means to become a critical agentic *bricoleur*. Such a *bricoleur* develops the sensibility and ability to continuously augment and adapt resources into new teaching and learning engagements, and he or she pays special attention to attenuating the challenges faced by students who are marginalized. This notion of being a critical agentic *bricoleur* speaks, on the one hand, to the socio-material entanglements that constitute the intersections of physical and digital resources and spaces, bodies, languages, and cultures in the science classroom. On the other hand, it also speaks to teachers' interest in giving agency to a digital application that the students use in their daily lives and shaping with it a space that promotes informal interactions contributing to classroom knowledge production and emotional bonding. On this topic of agency, the case study presented by Jaldemark, Eriksson Bergström, and Mozelius (Chap. 10) contributes thoughtful implications of addressing the students as co-designers of the orchestration of location-based games and mobile devices in the educational setting. The teachers linked content of schooling with the game Pokémon GO, a location-based game that is a common phenomenon entwined with the everyday lives of many children. The authors' work showed that by giving agency to such a game, the teachers obtain children's attention and build conditions for meaningful learning of mathematics. As such, these chapters showcase diverse instances of how the construct of agency can help explain how the various materials and symbolic technologies (Säljö, Chap. 2) become entangled with people, their practices, and the social order, and, by doing so, they can form hybrid arenas wherein new roles and agencies are enacted. Perhaps some of the radical transformations that are often mentioned in discourses about the use of digital technologies in education can be better explained and empirically demonstrated with a perspective of the agency that emerges from the relations between digital technologies, things, and people in educational contexts (Damşa, Kirschner, & Andriessen, 2010).

#4 Considering Values

Often, discourses about digital technologies in education fail to engage with the values that underlie the design of such technologies or the policies that are driving the use of digital tools in educational settings. The authors' contributions in this edited volume subtly note that an interest in the material conditions of everyday educational practices is concomitant with the scrutiny of the values that are either reflected in the design of the technology at hand or in the pedagogy put in practice by the teacher—and her institution—using such technology. This is clear in the contributions that unpack the teachers' attempts to appropriate and further design the digital technology via its use. Such contributions recount the teachers' expectations and their cognitive and sensorial experiences vis-à-vis a service, app, or platform that does not deliver the educational value that has been promised. A discussion on educational values is needed in our field. We need to speak more precisely and substantially about the underpinning values of learning and teaching in the digital age.

#5 Creative Critique

The chapters in this edited volume illustrate the importance of looking beyond technology-enhanced learning and the need to study practices and designs of digital technologies in relation to the social, cultural, economic and political realities of current educational systems. In this sense, this volume resonates with what Selwyn (2010) underscores: "whilst issues concerning the design, development and implementation of 'effective' learning technologies will continue to be of central importance to the field, it is reasoned that greater attention now needs to be paid to how digital technologies are actually being used – for better and worse – in 'real-world' educational settings (p. 65). Using different methodologies and concepts, the authors of the qualitative studies reported in these chapters critically engaged with the question of how digital technologies are *actually* being used and what emergent practices are bound to these technologies. Such a critical stance operates here in distinctive ways. Some studies aim at debunking, revealing, and unveiling "hidden interests, (f) actors, fields of power, rationalities, and so on, that frame what is, what can be done and how this should be done" (Decuypere & Simons, 2016, p. 38). Others instead aim at scrutinizing how settings are relationally composed and at bringing together different actors (Decuypere & Simons, 2016). Yet, both approaches are concerned with provoking creative critique. Creative critique is here understood as the ability to intervene in discourses and realities so new insights about how we relate to technologies for learning and teaching are generated (cf. Decuypere & Simons, 2016).

In conclusion, we believe these five take-away messages are giving shape to a research agenda aiming to contribute to a new knowledge foundation on the multiple relations that assemble teachers, learners, researchers, designers, cultural tools, and symbolic technologies. We invite the reader to be part of this adventure by reimagining studies of technologies in education.

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Chapter 2
Materiality, Learning, and Cognitive Practices: Artifacts as Instruments of Thinking

Roger Säljö

Abstract Human cognition generally is construed as an abstract activity involving symbol manipulation in the mind/brain of the individual. A corollary of this position is that the unit of analysis in research is the isolated mind. However, human cognitive practices generally take place in interaction with others, and, furthermore, they rely on the use of (socio-)material artifacts (documents, computers). One of the most distinctive features of *Homo sapiens* is the capacity to convert ideas into artifacts that support intellectual and physical activities, and that later will intervene in our daily practices. In this sense, artifacts are important outcomes of human learning that contribute to the building up of a cultural memory and that give the human mind its distinctive hybrid character where thinking relies on the use of artifacts that have emerged in society. As a consequence innovations continuously change our cognitive practices and capacities as is illustrated in the chapter.

Keywords Learning and artifacts · Cognition and materiality · Cultural tools · Cultural memory · Socio-materiality and thinking · Symbolic technologies · Learning in everyday life

Introduction

In experimental psychology there is a phenomenon referred to as "tip-of-the-tongue" (or "TOT"). This phenomenon, vividly discussed already by James (1890), refers to the familiar feeling of almost recalling a piece of information, be it a word or part of a word, a name or the title of a book or picture. We feel that "recall is imminent" as Brown and McNeill (1966, p. 325) put it in their seminal study of attempting to induce TOT experimentally. As a feeling that is part of everyday life, TOT is widely recognized outside the narrow circles of experimental psychologists. In a study by

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Reason and Lucas (1984), more than half of the respondents reported experiencing TOT like states every week (cf. Brown, 1991, for further discussion of when and where TOTs occur). Research on this phenomenon continues to this very day in fields such as memory, psycholinguistics, language learning, and so on (cf. Lampson, Gray, Cibas, Levy, & Loscalzo, 2016; Pureza, Soares, & Comesaña, 2016).

TOT poses a challenge from epistemic, theoretical and methodological perspectives for studies and research questions explored in this volume on issues of materiality and cognition. While TOT is a well-documented and robust phenomenon, and there is a vast number of empirical studies that testify to its existence, it also demonstrates a dilemma. If we want to understand how people deal with such states of mind and what they mean in daily activities, TOTs—the focus on recalling information—may not be useful. If we construe the human mind as an autonomous cognitive unit disconnected from external support, we will find that TOTs are probably as common today as they have been, and, most likely, we are no better or worse at solving such challenges than people have been before us. An alternative picture would appear if we analyze how people, in functional terms, deal with such states of mind today as opposed to, lets us say, in the middle of the twentieth century, when the empirical research on TOT took off. The expression "in a functional sense" here refers to the epistemic practices they are likely to engage in when facing such situations; how do they deal with the problem? In the current cognitive ecology of many societies in the world, people will immediately turn to their smartphones and a search engine to resolve a TOT situation. They will enter information relevant for what they are looking for (a part of the word, of the name of a person, of the title of a film, etc.), and they will search their way through the information displayed to obtain what they are looking for. In other words, we rely on external artifacts that connect us to the cultural memory of our society (Donald, 2018), and, in addition, we are currently developing literacy strategies for searching and validating information under such circumstances. The finding of the information in the latter context is a joint achievement involving a person and an artifact with a considerable repertoire of resources for searching, manipulating and displaying information supporting the activity of finding an answer; that is, both constituents of the situation—the user and the technology—exert some agency in the situation. Many of the strategies we have developed in such contexts are recent and follow in the footsteps of the spread of smartphones, the Internet, search engines and constant connectivity; elements of our cognitive and communicative ecology that are recent, appearing during the past 25 years or so. The ways in which we search for information in such settings are different from those that applied to situations in which we had to rely on our own memory or on writing and print technology. As Giddens (2002) argues, our "access points" to knowledge and information have changed, and, as an example, the particular problems of TOTs are now resolved differently as are many other instances of remembering and information search.

When studying, and when trying to theorize, cognitive capacities in a functional sense and as they are part of everyday activities, we thus face an interesting dilemma. Either we construe the mind as an isolated unit processing information detached from bodily, material and social ties and support. As a corollary of this position, we search for cognitive activities by localizing them inside our heads as cognitive schemas or processes; perhaps we even try to localize them in the biological substrate of our brains as is the dominant strategy in the neurosciences. Alternatively, we follow the suggestions by scholars such as the evolutionary psychologist Donald (2010), the anthropologist Lave (1988) and many others of construing cognition as embedded in practices that include other people and material artifacts. Donald suggests that humans, unlike other species, are best conceived as having "hybrid minds" that operate in collaboration with external storages such as texts, maps, calculators, digital media and a range of other "exographic" resources that have emerged through history. Lave argues that cognition is "stretched out" between people and between people and artifacts. In the latter conception of cognitive practices, the mind gains much of its power through the "mergers and coalitions" (Clark, 2003, p. 3) with artifacts that exist in the world and that have become constituents of our intellectual (and other) activities.

Technologies, Learning, and Cultural Memory

Technologies in themselves are products of learning, they testify to the capacity of *Homo Sapiens* to transform ideas into artifacts. By inventing artifacts such as the wheel, hammers, bows and arrows, trains and excavators, humans (and our predecessors in the hominid lineage; the oldest stone tools date back some 3.3 million years and even precede the appearance of *Homo habilis*; cf. Harmand et al., 2015) have extended their physical capacities well beyond what nature has provided us with. Through processes of design, we have altered the world we live in, and, as a consequence, our abilities to perform physical work, to travel, to hunt and to engage in most other activities are not constrained by the natural powers of our bodies. A heavy container can be loaded on to a large freighter by means of a crane controlled by a joystick, and in modern forestry a tall tree will be chopped down, peeled off, sawn into pieces of suitable length and loaded onto a lorry by means of a machine operated from an instrument panel in the relative comfort of a warm cabin. This designed nature of our environment is obvious in almost everything we do in modernity, and few would take issue with the nature and implications of such technological breakthroughs and their impact on our everyday lives.

It is equally obvious that the phenomena that we refer to as cognitive processes have undergone similar changes, provided we accept the idea of a hybrid mind. Our brains are the same, and they have been the same for a very long time, but how we use our brains has been changed. Cultural innovations have radically changed the ways in which we think, reason, remember, perceive and so on. Our capacities for remembering have been dramatically extended by the uses of texts, our visual perception has been amplified by tools such as spectacles, microscopes, binoculars and X-ray technologies, and our capacities for calculating have been transformed by the abacus, the slide rule, mechanical calculators, digital calculators and, in recent decades, by a wealth of highly specialized software, to mention but a few examples.

The cultural evolution during which external support for cognitive practices have developed goes back a long time, although, in comparison to the general development of artifacts, we are still in relatively recent times. Traditionally, the symbolic cultural revolution has often been said to have appeared around 40,000 years ago, but, as archeologists continue excavating, the date is pushed further back in history. At present, the claim is that the earliest preserved instances of intent symbol-making go back some 60,000, which is the dating of the famous engravings on egg-shells found in South Africa by Texier and colleagues (2010). But, most likely, we have not seen the end of this dating story yet (in fact, as this is written, a cross-hatched pattern made with an ochre crayon dating back some 73,000 years has been discovered in the Blombos Cave in South Africa, cf. Henshilwood et al., 2018). Later examples of intent symbol-making are stone-carvings or paintings and various artifacts with inscriptions considered to represent kill scores, lunar calendars and other information (d'Errico, 1998; Marshack, 1972). Even though the interpretations by scholars of what many of these early signs represent often differ (d'Errico, 1989), there is acceptance that they are intentionally produced signs serving memory and other social functions of significance to a community. Thus, what we see appearing in history is what Donald (2010, p. 70) refers to as "symbolic technologies," that is, tools created over millennia to "represent, communicate and store knowledge" and information.

Writing: Cognition Goes Material

The most important symbolic technology developed in the history of humankind is writing. Written language appeared some 5000–6000 years ago, depending on definitions (Harris, 1986; Schmandt-Besserat, 1981) in the so-called city states in Mesopotamia in present day Iraq (Kramer, 1981). Here, a new and much more diversified economy and society with a high division of labor emerged. City-dwellers could no longer cultivate land or keep animals to secure food. The city relied on continuous supply of food and other goods, on transport, and it had to provide other communal resources such as a defense, a legal system, and taxation to fund the infrastructure and services provided. Writing became the technology by means of which such functions could be coordinated and controlled: contracts could be written, receipts issued, people and properties registered, and so on. We see the emergence of "document societies" (Thomas, 2001), where specialized symbolic technologies began to complement the human memory as a repository of information and knowledge.

As Donald (2008, p. 197) puts it, the "human brain is adapted to the existence of cognizing mind-sharing cultures that far exceed the individual in terms of their ability to store and transmit accumulated knowledge and skill." In "mind-sharing cultures," minds, and even brains, and culture coevolve. Extended use of cultural sign systems such as written language and number systems has been shown to affect the patterns of brain activation and lateralization (cf., e.g., Dehaene et al., 2010; Donald, 2010;

Qin et al., 2004). These observations of biological correlates of the uses of exographic sign systems testify to the plasticity and flexibility of the human brain/mind, and an extraordinary capacity to accommodate to changes in external conditions.

The cultural and cognitive dynamics introduced by writing as a symbolic technology, thus, are multilayered and quite dramatic. A written language makes it possible to cumulate information, knowledge and human experiences at an unprecedented level. The cultural memory of a society utilizing written language can expand without any limits, and the cumulation of information and knowledge is in no way limited by memory capacities of individuals or even groups. At another level, writing triggered technological development where new instruments of writing (styli, lead pencils, typewriters etc.) and new materials for writing on (clay, wax, parchment and eventually paper) emerged. Libraries represent another obvious institutional outcome of written language of significance for expanding the cultural memory. The invention of the printing press in the fifteenth century is one of the most transformative technological changes in history. Scripts, arduously produced and expensive, were replaced by printed books that could be mass-produced (Eisenstein, 1985). The increasing capacity for disseminating information and knowledge implied that wide groups of people could avail themselves of the insights documented in the cultural memory. At yet another level, writing changed societies and individuals by providing new conditions for "mind-sharing cultures." Engaging with written language is both an internal, cognitive act of reading and/or writing, and, at the same time, writing is "out there"; it exists along with other social artifacts of culture, and forms part of a broader social context" (Barton & Hamilton, 1999, p. 799). Thus, the uses of written language—that is, literacy practices—changed both minds and societies, people had to learn to make meaning through reading for societies to be able to organize institutions and daily practices by means of written language. And, vice versa, for societies to develop, the minds of citizens had to be shaped through instruction and systematic training in the context of schooling in order for them to participate in literate practices. These consequences of writing for human cognition have been demonstrated through a large number of research studies ranging from neuroscience (cf. above) to psychological and anthropological inquiries (Goody, 1986; Luria, 1976, cf.; Scribner & Cole, 1981). This development is a clear illustration of the idea of coevolution of minds and symbolic technologies.

Put differently, written language (in a broad sense and including representations such as maps, drawings, and registers) serves as the interface between individual minds and the cultural memory. That is why it occupies such a central position in many societies, and why most representatives of contemporary education stress the importance of improving literacy skills. In addition, a cultural memory organized in this manner exerts a powerful impact on the cognitive (and physical) practices in society. It is thus not a passive container storing the past. As Donald (2018, p. 21) puts it, the:

> memory system of a culture is thus much more than a repository of past experience and knowledge. It is also an active cognitive force that influences thought and the representation of reality. It structures the collective individual activity of a population by linking together, in a set of complex social networks, the cognitive resources of an entire population. Within its embrace, networks of people exchange perceptions of reality, make decisions, share

> memories, form consensus on what will be remembered (and forgotten), and stimulate one another to generate thoughts and representations that are otherwise extremely unlikely to appear in socially isolated individuals.

While writing serves important functions for storing information and knowledge, it thus also exerts cognitive force and provides powerful means of organizing and manipulating information in collaboration with the artifacts of culture that are integrated into our practices. Examples of this are plentiful in history. The emergence and use of tables and tabular representations shortly after the invention of writing in Mesopotamia are an interesting case in point (cf. Campbell-Kelly, Croarken, Flood, & Robson, 2003). In tables, information could be organized in two dimensions by means of rows and columns. The unit thus created—in something that we today recognize as a cell—represented information under a heading, such as salaries during a given period. On the rows, the names of the recipients, such as priests, soldiers or public servants, could be given. This intellectual technique served important documentary functions in increasingly complex administrative routines. But, in addition to documenting transactions, the tabular representation became a thinking tool with features such as totals and subtotals in two dimensions, where the information in the columns and rows could be summarized, reflected on and argued about (Robson, 2003, p. 26). These procedures paved the way for important abstract functions such as auditing of transactions, and they provided overview over complex social activities.

The tabular representations that go back some 4500 years must be seen as major cultural and intellectual breakthrough with consequences for the future and for activities in many corners of society: astronomical tables, logarithmic tables, nautical tables, and so on. They may also be seen as predecessors of spreadsheets in the digital age. Appearing in the 1970s, the spreadsheet (with Microsoft Excel as the most well-known software) represents a continuation of the paper-based table in terms of how the information is organized in two dimensions on the screen. But in a sociogenetic perspective, and even though the "screen of a personal-computer shares the two-dimensional character of a writing surface," it has "two additional properties—easy erasure, and the ability to act as a "window" onto a much larger virtual surface" (Campbell-Kelly, 2003, p. 324). Easy erasure implies that the information can be altered and that the consequences of such changes become visible throughout the table. The flexibility that this affords implies that the user can manipulate the values in order to analyze the material and, in addition, ask "what if" questions as Campbell-Kelly points out. From a cognitive, and practical, point of view this is a very significant feature of the spreadsheet in the sense that "what if" questions are interesting for modelling, planning, and evaluating hypothetical alternatives in many settings, for instance when taking decisions on investments or other economic transactions and when attempting to predict future developments.

The capacity of the spreadsheet to work as a "window" onto a virtual world implies that it operates as a resource for managing and analyzing an infinite number of data sources and databases where the logic of the organization of information in spreadsheets is functional. Thus, the spreadsheet operates as a key or grid that stretches out into a world of data and databases that are formatted in compatible manners. Databases may be designed, built and exchanged, and they may be bought and sold across the world just as any other commodity. The operations to be performed by users are structured partially through the particular formatting, partially through the interests and capacities of the user in a situated practice. Both elements of the activity are necessary: symbolic technologies and capable human minds in search of information or knowledge.

Materiality as Constitutive of Cognition

At a very general level, the engagement with material objects has always served as a trigger of human thought and conceptual development (Malafouris, 2013). It is by externalizing ideas and attempting to implement them in physical form that human conceptual resources have expanded. In designed worlds, there is thus an intimate link between materiality and cognition, and, as Cole (1996, p. 117) puts it, artifacts "are simultaneously ideal (conceptual) and material." The very existence of an artifact is premised on the fact that material objects have been transformed and shaped by ideas and practices.

This duality is even more obvious in the case of symbolic technologies as illustrated in the evolution from Sumerian tables to contemporary spreadsheet software: we are dealing with material and conceptual entities that have been shaped through history and that are implemented in artifacts, and sometimes refined over centuries or even millennia. An important point here is that these technologies are not just representations of the world, rather they are constitutive elements of the enactment of thinking and reasoning in social practices where they serve as powerful "cognitive amplifiers" (Nickerson, 2005).

In the perspective outlined here, artifacts and cognition are intertwined in a distributed and constantly evolving system of thinking and symbolic technologies by means of which human reasoning is enacted in practices. Thus, documentation is more than mere registration of information. It is a cognitive act per se where issues of what and how to document have to be addressed, and documentation provides overview and systematicity where a complex reality can be simplified and made transparent (Mäkitalo & Säljö, 2002). Later, capacities to manipulate and operate on what has been documented have increased through the invention of intellectual techniques (such as those inherent to tables and spreadsheets) and artifacts (such as calculators, computer software). Such developments imply that current users of artifacts and conceptual systems operate on the basis of experiences that stretch over long periods. Many of the decisions that have been taken in the design of mundane artifacts have been "black-boxed" and are not attended to by the user as Latour (1999) argues. The user of a digital game or a search engine may have very little understanding of how the technology functions, but they can still become very skilled users of the artifact.

But this coordination between minds, materiality, and symbolic technologies is at the heart of the human capacity to think, learn and transform reality. In a sociogenetic perspective this is visible in artifacts such as rulers, compasses, clocks, speedometers, databases, and navigators, which represent not just a material legacy from previous generations but also an intellectual one. In contemporary society we are witnessing an intense evolution of such technologies with increasingly specialized functions. The traditional online calculator has been further specified in its design to adapt to the needs of currency conversion or to serve as a tool for house buyers when estimating costs for mortgages at different interest rates. The conventional weather forecast has been supplemented by apps with dynamic weather radars that make it possible to follow and anticipate the weather across the globe. The algorithms built into such symbolic technologies remain largely hidden for users, who need to understand how to enter information and how to evaluate the outcomes.

An illustration of such a process of developing a symbolic technology that allows us to conceptualize complex events has been analyzed by (Fauville, Lantz Andersson, Mäkitalo, Dupont, & Säljö, 2016; Lantz-Andersson, Fauville, Edstrand, & Säljö, in press). We explored how the problems of human impact on the environment may be visualized and communicated in a transparent and relevant manner in order to support education, public awareness and political debate. This has been achieved through the invention of a highly specialized artifact, the Carbon Footprint Calculator (CFC). The concept of Carbon Footprint (CF), originally based on the metaphor of an Ecological Footprint, was invented in the 1990s (Wiedmann, 2009). CF is defined as the amount of CO_2 and other greenhouse gases produced by a person's activities in a given timeframe. The basic idea is that people report on their daily activities in areas such as housing, transport, food habits, shopping etc. Figure 2.1 illustrates a part of the home energy and appliances section of a CFC (www.i2sea.stanford.edu/calculate).

When the person reports on his or her heating system and enters her values into the different boxes, the calculator converts the information to CO_2 emissions expressed in kilograms. At the bottom of the page, the value obtained may be compared to averages of the country the person lives in or of the world. The interface is familiar for anyone who is digitally literate, and the nature of the task of entering values is familiar. The outcomes—that is, the estimates of footprints from various activities—may then be integrated into reasoning and arguing in discussions of various kinds of comparisons and when considering how one can reduce one's own footprint by changing habits. Thus, this symbolic technology lends itself to exploring a range of "what if" questions of concern for educational settings but also for citizenship and decision-making in everyday life.

In the wake of these developments of citizens gaining conceptual access to their footprints, other consequences may follow. For instance, houses and products such as cars, dishwashers or fruit will be sold with information about their impact on the environment. In this sense, public awareness of how to address environmental problems may increase. What a symbolic technology of this kind does is that it structures and gives users access to a topic that would be difficult to address in any other manner. The concepts themselves are abstract and the calculations built into the device would be difficult, if not impossible, to engage in without the tool. From

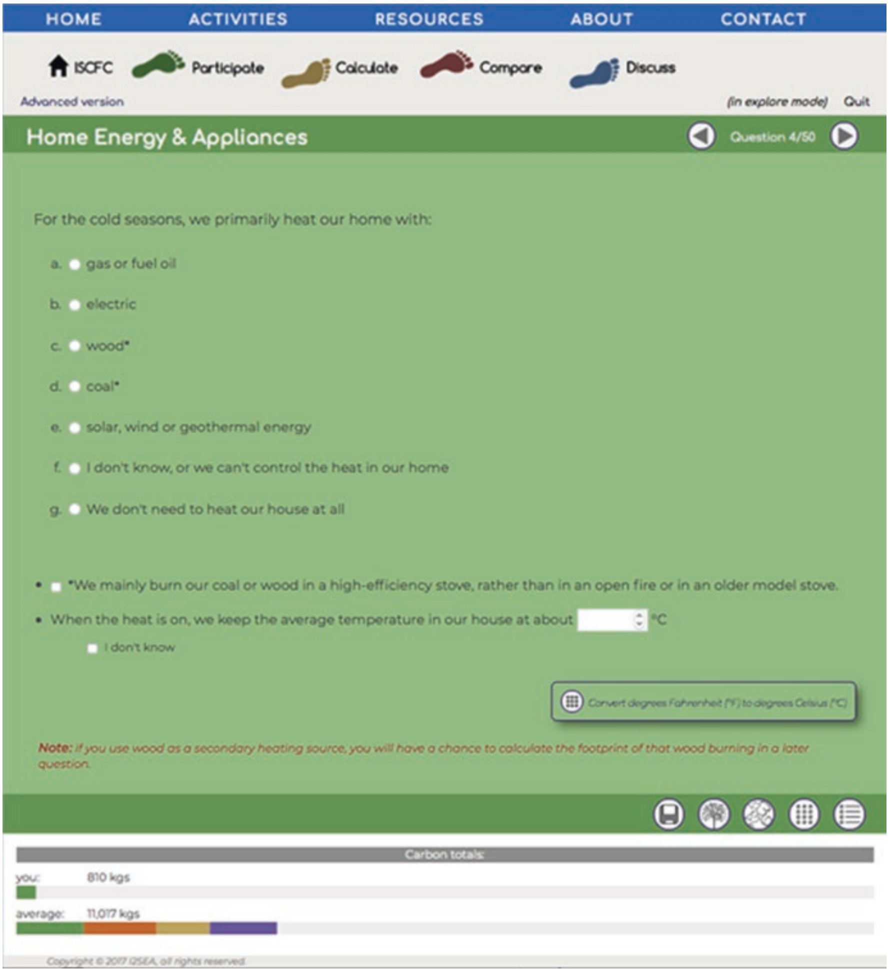

Fig. 2.1 Home energy and appliances section of a Carbon Footprint Calculator (permission Géraldine Fauville; www.i2sea.stanford.edu/calculate)

a cognitive point of view, a technology of this kind illustrates of how tools allow us to explore and reason about more than what we in some sense know (Wertsch & Kazak, 2011). By using the CFC we can structure a problem and convert various sources of information to arrive an aggregate output that is relevant for learning and for citizenship in contemporary society. Thus, the symbolic technology does far more than calculate. It is a conceptual tool that structures a problem in ways that make it accessible for reasoning about complex issues.

Of course, symbolic technologies of this kind require competences and skills of users, and they are black-boxed. Most users will not understand the assumptions regarding climate change that are built into tools of this kind, and there will also be conflicts among experts about exactly how estimates should be made and what algorithms that are accurate. Thus, trust will be a matter of concern in such settings.

Conclusion

It is interesting to observe that current perspectives on learning and cognition, and the role of symbolic technologies for thinking, were anticipated in Vygotsky's (1981) thinking almost a hundred years ago. In his short essay "The instrumental method in psychology" he sketched his ideas about the role of "cultural tools" for human learning and knowing. In this short text, originally a lecture, he argues that tools are constitutive of what he refers to as "instrumental acts" of thinking. In such instrumental acts, "artifical formations," that is, human-made signs and sign-systems, reorganize mental functioning and introduce "several new functions connected with the use of the given tool and with its control" (p. 139). Such an artificial tool also often "abolishes and makes unnecessary a number of natural processes, whose work is accomplished by the tool." (*loc. cit.*). The examples given illustrate how cultural tools, symbolic technologies, are integrated into our thinking (and communication), and how they—in Vygotsky's terms—contribute to reorganizing intellectual practices and instrumental acts of thinking and arguing. In this sense, artifacts may be physically out there, but in spite of this, they are constitutive elements of the thinking and knowing of a hybrid mind.

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Chapter 3
Unpacking Emergent Teaching Practices with Digital Technology

Teresa Cerratto Pargman

Abstract What changes when digital technology is used in the classroom, and how do we identify these changes? These questions motivated the present study, which sought to contribute to the discourse on the digitalization of schools from the perspective of teachers' everyday practice. The analysis was grounded in the scrutiny of 11 semi-structured interviews and field notes stemming from ethnographic observations carried out in classrooms, breaks, and teachers' workshops. The data were analyzed in terms of materials, competences, meanings, and experiential qualities (i.e., referring to how certain properties of a digital design are experienced in use). The experiential qualities that emerged from the analysis of the data show an interrelation between the elements of practice; in particular, they reflect a visible, problem-solving and adaptive teaching practice that develops with the use of digital technologies in the classroom. Such a practice is characterized as effective, evidence-based, and liberated from time and space communication. The implications of these findings are discussed in relation to, the emergence of the teachers' practice of experimenting with the digital materials, and the emergence of a managerial communication practice in the elementary school. The chapter contributes to the discussion of the tensions between incremental and radical changes in teaching with digital technologies and offers an elaboration of the relevance of a lens on practice in studies about technology and education.

Keywords Digitalisation · Digital technology, Tablets · Teaching · Learning · Design · Socio-materiality · Change · Practices · Communication · Experiential qualities · Managerial communication · Nordic schools

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What Changes with Digital Technology in the Classroom, and How Do We Identify these Changes?

The digitalization of the school is not "just" an information technology project, but rather a project that is producing profound changes that affect school practices and the school as an institution (Grönlund, 2014). What are these changes, and most importantly, how can we best describe and unpack them? The existing literature on the topic reflects a knowledge gap. On the one hand, substantial effort has been devoted to studying how the design and use of digital technologies *should be* so they can promote learners' autonomy and enhance their performance and collaboration (Al-Emran, Elsherif, & Shaalan, 2016; Geer, White, Zeegers, Au, & Barnes, 2017; Pachler, Bachmair, Cook, & Kress, 2010; Sharples, Arnedillo-Sánchez, Milrad, & Vavoula, 2009; Sung, Chang, & Liu, 2016). However, on the other hand, few studies have demonstrated how digital technologies are *actually used* in the everyday classroom (Lave, 1988; O'Malley, Suthers, Reimann, & Dimitracopoulou, 2009; Sörensen, 2009; Stahl & Hesse, 2009; Wenger, 1998).

This chapter seeks to fill this gap. In doing so, I attempt to come to grips with the changes that are concomitant of the digitalization of the school in the Global North. In this context, this work argues for the need to focus a lens on teaching as a socio-material practice (Bolldén, 2015; Cerratto Pargman, Knutsson, & Karlström, 2015; Decuypere & Simons, 2016; Fenwick, Edwards, & Sawchuk, 2011; Johri & Olds, 2011; Landri, 2015; Sörensen, 2009). The argument is built mainly on the following observation: that the dynamic and types of teaching practices that emerge with the use of digital technologies configure and shape learning, and, ultimately, ensure the formation of school knowledge in the digital age. Approaching teaching practices as socio-technical assemblages that are constantly emerging opens opportunities to unpack the relational composition of these practices. The study of teaching practices was conducted in three elementary schools in Sweden. The empirical data were mainly collected in 11 semi-structured interviews with teachers and IT pedagogues, as well as a series of ethnographic observations performed in the school during lessons, breaks, and teacher's workshops. The study was carried out in December 2013 and October 2014. The goal was to unpack and discuss the main challenges of and opportunities for using mobile technology, particularly the tablet, in the school classroom. The study shows the emergence of two main practices that characterize the ongoing process of digitalization in the schools studied: (1) the teachers' experimentation with digital materials, which contributes to visible, problem-solving and adaptive teaching practice; (2) the teachers' managerial communication, which is effective, evidence based, and liberated from time and space communication in the school. These findings present implications for the type of incremental and radical transformations that are currently affecting the school. In particular, the study draws attention to a teaching practice that takes advantage of the interactive and multimodal affordances of the digital materials, introduces variety in learning, but resists engaging with the deeper pedagogical changes that may be linked to the learners' and digital material's new agency in the digitalized school.

The study also points to new values underpinning communication in the school that seem to be linked to customer service rather than learner-centered communication. The chapter ends by discussing the relevance of the socio-material practice lens in studies about technology in education.

The Need for an Approach Informed by *Practice Theory* in the Field of Educational Technology

Wenger (1998) alerted us that the interest in issues of practice can be traced back to "the work of Marx in 1844 on the use of the notion of praxis to denotate the socio-cultural context for a materialist account of consciousness and the making [of] history" (p. 281). Since then, variegated theorizations in philosophy and in the field of social sciences have conceptualized human practice. Emphasizing the richness of late theoretical developments, Schatzki (2001) made it clear that there is not a unified approach on practice but rather many different approaches. By reading Schatzki (2001 p. 7), we learn that most of the theorizations on practices conceive practices as arrays of human activity that are underpinned by "capacities such as know-how, skills, tacit understandings, and dispositions" and a minority of them underscore that the activities bound into these practices also include those of nonhumans such as machines. The latter is called the post-humanist view on practice, which has developed in science and technologies studies (STS), and in the field of education, has been advanced by Sörensen (2009) and Fenwick et al. (2011).

Following Schatzki (2001) we understand that current practice approaches can be characterized by two central traits. One of these traits is the idea that practice is embodied, that is, entwined with the human body, meaning that bodies and activities are constituted within practices. On this point, the practice theory embraces the embodied cognitive capacities. According to Schatzki (2001), it is "rooted in the realization that the body is the meeting point both of mind and activity and of individual activity and social manifold" (p. 8). This specific trait places emphasis on human-embodied capacities such as know-how, skills, tacit understanding and dispositions instead of mental entities such as beliefs, desires, emotions, and purposes (cf. Schatzki, 2001). This practice approach resonates with the work of the anthropologist Jean Lave in the field of learning sciences, and most precisely, her influential work on cognition in practice (1988) and situated learning (Lave & Wenger, 1991). In her work, Lave (1991) sharply criticized cognitive approaches and argued in favor of a lens on social practice for a deeper understanding of the complexity of human thought as it unfolds in everyday life. Lave's critique reflected the need to link "doing with knowing" and thereby redefine learning as situated and developing at the core of an "open-ended process of improvisation with the social, material and experiential resources at hand" (Lave, 2009, p. 204). The situatedness of learning that Lave claimed relates to the central place that she gives to the human body and the social context in learning activities. The influence of social theory in her work is crystal clear on this point, as she introduced the social in learning activities by laying the foundation that learning can be seen as a field of embodied, materially interwoven practices that are centrally organized around shared practical understandings.

Another trait of the practice theory is the variety of materialist developments. Materialist approaches argue that to understand specific practices, it is relevant to capture the material configurations that constitute them. Two varieties of post-humanism are here distinguished by Schatzki (2001): *objectivism*, developed by sociologists such as Pickering (2001) and Knorr Cetina (2001), and another variation characterized by the *prioritization of practices over individuals*, which argues that the mind is, at least to a significant extent, constituted by practices.

In the field of education, it is the latter variety that gained momentum based on Sörensen's work on the materiality of learning (2009). In her work, she found inspiration in the use of actor–network theory (Latour 1988, 2005; Latour & Woolgar, 1986) and in the field of STS. Sörensen (2009) clearly problematized the fact that "technologies and materials have been and still are broadly neglected as part of the constitution of knowledge in particular and of social processes in general" (p. 8). In doing so, Sörensen ascribed to the idea that subjects and agents are bound to practices, and that practices, not the mind, are now the central phenomenon in human life. Such an understanding of practice has implications for the conception of knowledge. Following Schatzki (2001), this particular variety of the post-humanism approach on practice conceives "knowledge as mediated both by interactions between people and by arrangements in the world" (p. 12). A corollary of this argument is that knowledge no longer belongs to individuals but instead is a "feature" of groups, together with their material setups. Following this line of reasoning, Sörensen (2009) posited the idea that as in science, school practices also produce knowledge, and that materials, for instance, digital technologies, participate in such production of school knowledge by configuring and shaping educational practices.

Faithful to the objectivist research, Pickering's (2001) work on social theory and the history of agency underscored the mutual constitution of material and human agency and called for studies on the sites of encounters between the human and the material, for instance, the human–computer interface. In the field of educational technology, Fenwick et al. (2011) explained that an understanding of the mutual coevolution of material and agency challenges our assumptions, such as that a knower is distinct from the thing that is known or that a subject is separable from an object, and also invited us to engage with the idea that things are performed into existence in webs of relations (cf. p. 3). More precisely, Fenwick et al. (2011) referred to Bennet's concept of the "force of things," which she explained by specifying that "the point is not that individual objects have agency but that force is exercised through socio-material assemblages" (p. 5).

These conceptual developments, originating from social science, are instrumental in the elaboration of a more nuanced understanding of the transformations that the use of digital technologies bring into schools. As teaching and learning are situated and embedded within a social context and culture (Lave, 1988) and bound to the tools making them possible (Kaptelinin & Nardi, 2006; Rabardel, 1995; Säljö, 2010; Vygotsky, 1934/1997), it is necessary to approach such social and material arrangements with conceptual lenses that help researchers to ascertain the negotiations, accommodations and struggles between their multiple facets (Fenwick et al., 2011, p. 2). As emphasized by Cerratto Pargman et al. (2015), an approach on socio-material practices in the learning sciences and education is needed, as it frames teaching and learning in the flow of everyday school practices, in which materials contribute a cultural practice within which learners and teachers, as individuals, operate (Lave, 1988; O'Malley et al., 2009; Stahl & Hesse, 2009; Wenger, 1998). A lens of socio-material practices is also relevant, as it intercepts the researchers' need to further develop a methodology that is able to critically unpack practices as they unfold throughout the course of the digitalization of the school.

A Simple Framework to Analyze Everyday Teaching Practices

In her book, *The Dynamics of Social Practice: Everyday Life and How it Changes* (Shove, Pantzar, & Watson, 2012), sociologist Elizabeth Shove asked, "how do practices emerge, exist and die?" and "what are the elements from which practices are made?" (p. 14). Considering these questions as central to understanding the transformation that education is currently undergoing, I have engaged with the simple conceptual framework suggested by Shove et al. (2012). Such a simple framework is grounded in Reckwitz's (2002) idea that a practice consists of interdependencies between diverse elements, specifically *material*, *competence*, and *meaning*.

According to Shove et al. (2012, p. 120), *materials* include objects, their tangible physical aspects, technologies, tools, the body, and the stuff from which objects are made. By *competences* or practical knowledge, the authors referred to the skills for the respective practice, as well as the know-how and techniques. *Meanings* are understood as the aspirations, ideas, values, and beliefs driving a practice that bring significance to the actions in a practice. The framework is grounded in the understanding that practices change when new elements are introduced or when existing elements are combined in a new way. By describing patterns of practices and their elements, Shove et al. (2012) attempted to describe and explain, in staudies about technologies in education, the dynamic aspects of social practices.

Shove et al.'s (2012) conceptual framework is meaningful for the following reasons: First, it includes *materiality* as a dimension of practice, which is a dimension that is often left out of accounts of educational practices (Sörensen, 2009). In the work of today's teachers and learners, the physical dimension, and in particular, digital materials play a central role in how and what we teach and learn. On this note, Kress (2003) called for the study of the materiality of literacy by pointing to the dominance of the medium of the screen over the book that has "changed the communicational landscape of the 21st century and questions contemporary conceptualizations of literacy and learning" (p. 242). Second, the framework refers to the element of *competence*, which is also highly relevant for our work, mostly in relation to the teachers' practices, and particularly, because of the wide range of competences between experienced and less experienced teachers engaging with digital technologies in their classrooms. Third, it refers to the element of *meaning*, which can help capture the motivation and incentives behind the teachers' efforts linked to the digitalization of the school.

The analysis of teaching practices from the perspective of material, competence, and meaning opens up the black box of teaching practices, which can facilitate valuable insights for educational technology. The analysis of how these elements are interrelated can lead to an account for transformation and innovation in school practices. The concept of experiential qualities that is chosen here has the potential to articulate how these element of practices relate to each other.

Experiential Qualities

Perceiving information technology as "the material without qualities," Löwgren and Stolterman (2005, foreword viii) underscored software designers' responsibility to decide on the functions, form, and structure of artifacts, as well as their ethical and aesthetical qualities. By coding and programming (designing) a computer application as a material without qualities, Löwgren and Stolteman (2005) indicated that such materials are constantly shaped by users in how they use the material. The design process can be seen as open, imperfect, incomplete, and fundamentally complex, as it becomes irremediably enmeshed with people's use and their social practices.

In this context, the term *experiential quality*—earlier called use qualities by Löwgren and Stolteman (2005)—refers to how certain properties of a digital design are experienced in use. Such qualities, perceived by the users, are linked to aspects that directly connect with the felt-like experience of using technology (McCarthy & Wright, 2004). Löwgren (2007) provided us with a list containing a few examples of experiential qualities identified from the spatiotemporal nature of the digital design materials. For example, he referred to the latency of media delivery in mobile phones, which gives an impression of the mobile phone's brittleness and unreliability. The experiential qualities that Löwgren spoke about can be assembled in a set of qualities that concern (a) the users' motivations for engaging with the digital artifact, (b) the immediate sensation of interacting with the artifact, (c) a set that has to do with the social outcomes of interaction, (d) a set of qualities pertaining to the structural features of the artifact as they manifest themselves while in use, and (e) a set addressing the induction of users' reflection upon their situation.

The analysis presented here can be situated within the latter two sets of qualities. The instantiation of experiential qualities associated with a specific artifact is made throughout the observation and understanding of the use of such artifact. Qualities are not given or predetermined but emerge from the interaction between the use and the computer system or app. Löwgren and Stolteman (2005) were clear on the point that the *experiential qualities* enunciated by the users can be transferable, meaning that the results of the user's experience can be communicated and documented. Specifying the experiential qualities of teaching practices contributes to articulate how the constitutive elements of practices relate to each other but most importantly, they provide researchers and designers with a vocabulary to express the teachers' felt experiences with teaching and communicating with digital materials.

The Methodology for Studying Teachers' Everyday Practice

The study was part of a project supported by the Swedish Research Council that aimed to describe and explain the intricacies and complexities of introducing tablets into school curriculums and practices (Cerratto Pargman, Nouri, & Milrad, 2017). The schools were selected by their respective municipalities to take part in the one-to-one tablet program initiated in 2011. This program consisted of providing schools with tablet computers (i.e., iPads and Chromebooks) and wireless Internet connectivity. We made contact with the teachers via the schools' principals, who we knew from past project collaboration. The principals introduced us to the chosen teachers, who were interviewed and observed during classroom lessons and workshops. This is an important piece of information because most of the teachers who participated in the study were familiar with mobile devices and were familiar with pedagogical development and the effective use of mobile technologies in school. Moreover, the participating teachers had a common pedagogical vision associated with the challenges of working with children for whom Swedish is a second language or who are weak in Swedish. In this respect, the teachers interviewed mentioned that they experienced their pedagogical work as quite centered on "giving a language to these kids."

The data collection started in December 2013 and was finished in December 2015. An ethnographic qualitative approach was adopted (Ito et al., 2009). The interviews covered the following themes: the teachers' general impressions about the use of computers in the school, their experiences about the use of tablets in their everyday teaching, their pedagogic standpoints and the constraints experienced when introducing tablets into the classroom. The interviews were conducted in Swedish, and they were audio-recorded and fully transcribed. Excerpts were translated only for the purpose of this paper. For the sake of anonymity, I refer to the teachers by pseudonyms. A detailed overview of the data collected, including the school subjects targeted, is provided in Table 3.1.

The data analysis was iterative and recursive, and it was guided by the following constitutive elements of social practices: materials, meanings, and competences proposed by Shove et al. (2012).

- By *materials*, I specifically refer to artifacts such as learning management systems (LMS), cloud services, Internet services, e-mail, tablets, desktops, laptops, mobile phones, interactive whiteboards, and their physical conditions in terms of interface, functionality, and affordances, as well as chargers, cables, notebooks, books, posters, and furniture.
- By *competences*, I refer to teachers' digital skills, communication competence and teaching know-how.

Table 3.1 Information about the teachers interviewed and their teaching grades

Teachers	Teaching experience (years)	Elementary school subjects	School
Kora	10	Mathematics	Municipal
Sam	5	Mathematics and Natural Sciences	Municipal
Linda	3	English, Swedish, and Swedish as a second language	Municipal
Sanna	7	English, Swedish, and Swedish as a second language	Municipal
Vera	7	English and Swedish	Municipal
Henrik	12	IT pedagogue	Municipal
Paul	10	IT pedagogue and English	Private
Bibi	11	Mathematics, Natural Sciences, and Swedish	Municipal
Ron	13	Art pedagogue	Municipal
Robin	17	IT pedagogue	Municipal
Klas	20	Natural Sciences—Author of several e-books	Municipal

- By *meanings*, I understand teachers' key motivational factors behind the use of digital technology as well as their aspirations with ICTs in the classroom, both bringing significance to teachers' and learners' actions in a practice.

The analysis focused on the relationship between the components of materials, competence, and the meanings of teaching practices studied through experiential qualities. The experiential qualities were identified via a thematic analysis applied to the transcribed interviews (Braun & Clarke, 2006). The emerging bottom-up semantic codes became the labels of the qualities. These experiential qualities functioned as the analytical sensibility that was able to articulate the interrelations between the constitutive elements of the teaching practices studied. The goal of this effort was to provide better insights about transformation and innovation in school practices.

Findings

The study was guided by the following questions: What changes with the use of digital technology in the classroom, and how do we identify these changes? These questions guided the analysis of two central aspects of the observed teaching practices: (a) teaching with apps, games, and films in the classroom and (b) communicating with the learners via the LMS. In the following section, I unpack the findings in terms of the experiential qualities of teaching and communicating with digital technologies.

Teaching with Digital Materials in the Classroom

This section refers to the teachers' experiences and reflections on the teaching they perform in the classroom with a set of material arrangements.

Materials

The materials were comprised by the use of the Internet, in particular, search engines and YouTube, game-based learning platforms, drilling educational apps, mostly for the subjects of Swedish, Swedish as a second language, and mathematics, use of the camera and film recorder, and the office suite of applications available on the school tablet. It also includes the teachers' desktop computers, the projector and the whiteboard where both the teachers' lessons and the learners' homework and presentations are shared during class.

Competences

In the classroom context, the teachers developed multiple types of competences, such as solving technical struggles on the fly, understanding compatibilities between computer programs, searching and testing educational apps, creating links between the learning objectives stipulated in the national curriculum, the analog and digital educational material already produced by them, and the new content and features offered by the new digital material. The teachers mentioned:

> *Some programs we have on our desktop computers we cannot run now when the children have the tablets because there are agreements that are lucrative for someone, but not necessarily for the school. (Bibi)*

> *It happens often that cables may not be dragged as they should be or that something has happened and the specific app you intended to use has disappeared and you notice just when it is too late. Sometimes, it may happen that you do not have the right to install anything… Or sometimes, as I said, it has not been possible to check it—the equipment in the classroom—out. Then, you are there in the classroom with your pupils and you are going to start your lesson and … it does not have to be so, but sometimes you can end up in that situation. (Linda)*

Teachers' experimentation with technology in the classroom also presents implications for the distribution of roles and power in the classroom. Here, one of the teachers explains:

> *There is always a student in the classroom who can do more than I can. Then s/he will shine a bit, and I have no trouble dropping the prestige there. They think, "oh, Sanna, you don't know how to do it, do you?" and then my answer is: "Well, no, I don't. I can't do it, but you can, can't you?" Well, that is good; it's perfect. (Sanna)*

The competences bound to the digital materials also speak of the teachers' need to gain knowledge about how the new material teaching conditions have a social impact in the classroom. These new material conditions shape the relationships between the learner and the teacher and ultimately distribute the roles and the power in the classroom.

> *I would say this: Be humble, don't be afraid to show you can't try it out, try it out and try again! That's what I would say to other teachers planning to introduce the tablet in the classroom! And accept help from the students. You can say this: God, this is not working! Is anyone able to do this? And then you solve it together. Because I feel that many teachers feel that, as teachers, we have to know what we are doing, and I understand that. You do not go unprepared to your lesson. This is the worst thing you can do. And I think the IT stuff is connected to it. You feel unprepared, perhaps not that you cannot do it, but you feel that if things happen and you can't…then you ask yourself: Where am I, what's my role in this? (Robin)*

Meaning

When asking the teachers about the meaning of putting so much effort into the integration of tablets in their everyday practices, they mentioned that although a lot of time is dedicated to making the tablet work in school, this technology is not radically changing their teaching model or pedagogical vision at large. Notwithstanding, they mentioned the novelty of being able to track each learner's progress and results, which is instrumental in facilitating individual-centered teaching. For the participating teachers, there is no doubt that the tablet is a fantastic resource for training abilities and developing aesthetic/creative skills. In particular, they refer to the apps with drilling exercices, online dictionaries, online translation services, and voice-recording, which make a significant difference for children who are weak in Swedish. Also, the access to images and sounds aids the teachers' communication with learners for whom Swedish is a second language.

> *Yes, the language is a huge thing here. We are constantly working with the language. It is great when you can combine pictures and different things. It's easier for them to understand. I can talk about something, but if I show them with my body and with pictures, they get it at once. (Kora)*

The rich multimodality and aesthetics of the learners' presentations, their capacity to express themselves and represent a topic through multiple communication channels and the use of games and the YouTube channel introduce *variation* in the teaching practice. One of the teachers explains variation in the following terms:

> *What I see is that the use of the tablet can offer the students … several different ways to learn; <u>variation</u> in teaching can increase because (…) you must be able to show (…), so you must be able to write on the board, you must be able to speak, the students must be able to read (…), use several tools to present materials in different ways and work with them in different ways. It is most useful with it—the tablet—(…). And above all, it may happen that we can reach students who are having reading and writing difficulties, and these difficulties for them may change, so there are huge benefit*s …. *(Sam)*

The participating teachers mentioned new teaching and learning possibilities associated with the use of the digital drilling exercices and earphones in the class and with the meta information or learning analytics data that are accessible through the use of learning platforms.

> *It is precisely this, that you can communicate material via LMS, and there, you can get the pupils to answer, to hand in work… It becomes easier to follow up on what they do … You can activate them; you can also follow up on who has completed the assignment and who has not, and you can also present material that is more complex there, and everyone has the chance to study it at their pace, and where they want to study it. It is an advantage that there is availability for the students any time. (Sam)*

However, such new possibilitiues in the teaching is not perceived as a radical change at the level of the pedagogy underpinning teaching or at the level of the values driving the teachers' school practices. As one of the teachers puts it:

> *It—the tablet—opens a new dimension in our teaching, but …there is no revolution. (Vera)*

Experiential Qualities of Teaching with Digital Materials in the Classroom

From the interrelations between the materials, competences, and meanings, the following set of qualities emerges that characterize how teaching with digital materials is experienced by the teachers:

Visible teaching alludes to the use of different kinds of interactive representations, and in particular, the use of visual resources, which prevails in the teachers' lessons through the sharing of images and films in their presentations. This quality, according to the teachers, is also prevalent in the learners' work.

Problem-solving refers to two aspects of teaching with the tablet: it has to do with the extensive use of apps in the classroom that offer drill exercises focused more on solving problems and on success than articulating the reasoning behind the procedures applied by the learners. It is also an experiential quality that is associated with the teachers' experimentation and testing in the classroom. The teachers experience that part of their teaching involves solving technical problems together with the learners.

Adaptive teaching connects to the fact that most of the apps and their functionalities available for the learners and the teachers are conceived from an individual point of view on learning. It is not unusual, for instance, that during a class on Swedish, the combination of using apps with earphones enables the following constellations: some learners engage in drilling exercises, others write stories with a book creator, others listen to stories, and another group works with translations. Moreover, the teacher's access to the learning analytics provided by some game-based learning platforms or the information available in the LMS contributes to a personalized form of teaching.

Teacher–Learner Communication with Digital Materials

In the increasing digital communication between teachers and learners, the use of the LMS occupies a central space in teacher–learner communication. The LMS are most often used as a socio-technical platform for teachers, learners, and parents through which they share lessons, instructions, presentations, messages, grades, calendars, schedules, feedback per school subject and the learner, as well as administrative tasks, such as the learners' presence and appointments such as development talks and informational meetings. I here engage with teachers' narratives about the use of the LMS in terms of constituting such communication experiential qualities.

Materials

The materials here in focus were the LMS, and in particular, Schoolsoft, Learnify, Showbee, cloud computing, the municipality's intranet school web, which provides access to functionalities destined for the administration, learners' documentation, access to e-mail, schedules, rooms, as well as diverse resources such as connection to the information provided by the school administration to ensure the management of education.

Competences

The following quotation illustrates a typical expression of the relation between the materials and the competence that is needed for assessing and interpreting the learner's performance and progress through the LMS.

> *Ok, I am showing you the tools that I use every day, the ordinary e-mail, the LMS that I showed you earlier, which is our order and remedy system, just that simple … here, we put the learners' grades. I communicate; I put our homework; here, I write my assignment; here, for instance, I have an assignment that is connected to a reading project that we had done during a term, and here, I connect it to the knowledge matrix… For instance, this person has read the Hunger Games, and thus, I wrote a comment, and I filled out the knowledge matrix … all of this comes straight into the subject matrix. The feature we are talking about has saved administrative time for teachers. It has helped us very much … I never write longer assessments…I can just write a comment on the assignment, and the matrix is included in the LMS, and for instance, like I said … this learner, let's say that we want to check his knowledge matrix or the basis for the grade he got. Then, I go under this school subject like this* (he points to the subject matrix that summarizes all the assessment performed by the teacher) *In this way, our teachers work with the learners, and they, the teachers, are confident that it works … So, we look at this learner's subject matrix, and here, we have the assignments that are connected to the matrix, and then, we can see that this learner has got good grades. He has grades of A in most of the assignments, and when he gets a grade B, he has access and can sees all this information* (the specific aspects of the subject that he needs to further develop in order to perform better). *And his parents see all of this. It is a transparent system… and we think this is good: a system that saves time, gives quality to teaching and contributes to the development of oneself. (Paul)*

The example points to the central role the subject matrix plays in the teacher–learner communication, which also includes the parents. The subject matrix that is generated by the LMS displays the partial results of all the learners' assignments assessed and the final grade, both connected to the criteria provided by the National Agency for Education, which are also included in the LMS. Such a matrix also includes three free writing fields: (1) a subject warning field allowing the teacher to document specific problems the learner has experienced with the school subject; (2) an action program field where the teacher refers to the abilities the learner needs to develop in order to improve knowledge in the subject, and (3) a comment field where the teacher writes complementary notes that are shared with the learner and the parents. The reading of the subject matrix is facilitated by the use of three colors: green, which means that the level has been achieved; yellow, which indicates that the student is still working to fully achieve this level; and red, which indicates that the learner has worked with this level but has not yet shown the necessary ability to complete it. By providing the teacher with such a holistic representation of the learner's performance on the specific subject matter at hand, the matrix is experienced as a tool that helps make the assessments tangible, grounded and shareable.

The specific competences that are observed here and bound to the LMS are documenting learners' assessments, knowing how to interpret the knowledge criteria stipulated by the National Agency for Education from each of the learners' assignments uploaded in the LMS; comprehending how the subject matrix and its colors are generated by the LMS; and making sense of the meaning of the results displayed by the LMS.

Meaning

When asked about the meaning of using the LMS or equivalent systems for communication, the teachers mention the value, which, for them, is the ability to count on a common platform, a repository, where all the teaching material and documentation is available 24/7. This is highly appreciated by all the teachers interviewed because it is perceived as a tool that helps to save time and that mitigates the feeling that teachers often experience in relation to struggling to ensure that all the learners get all the information presented during the lesson. On this note, one of the teachers explains it as follows:

> *… We've got iPads in this school and … I have put up my entire teaching on the Internet … and the reason for this is that I gave up paper and such, and I also gave up running all week and distributing 300 papers to all the learners. So now, I have put up all courses online. I have put instructional films, assessments' basis, assessment matrices, homework, tests: Everything is available. So now, I refer to the iPads … So, yes, if they—the learners—lose them—the papers—I tell them to go and look only at the iPad. Now, I was sick a few weeks ago, and then, I took care of my teaching via my replacement and the LMS, so it was brilliant. And at the same time, … we have many pupils who are weak in Swedish. So, I go through the lesson like a regular debriefing, and I make sure I can share short movies with or without sound that only show what I am doing or what I have been talking about during the lesson. And then, yes, that's great because that makes me realize that before I had the*

problem that … I was asking myself: What am I doing wrong that they do not listen; they are not focused … what's going on? Why they don't understand it? Because when we are applying something in practice, we are not always on the same page … there are five or seven pupils in each group, so I don't have time to help those who have understood what they have to do and are interesting in going deeper into the subject. And now I do like this: I ask them even before the lesson to check the instructions [in the LMS], and then, there are some who do check them and some who don't, and when we have the lesson, and I go through it with them, and I say this: Check the instructions again. And thus, they do it, and I can help those who want to learn more. So, for me, this has been a real help. It's like I have become two teachers. (Robin)

The LMS, the e-mails, the websites, and the cloud computing become entangled with the teachers' planning, delivering, monitoring, and assessing competence, but most importantly, with the teachers' pedagogy and their ways of organizing their communication in the classroom and sharing responsibility with the learners about their learning. Such entanglement is constitutive of an emergent management practice that can be characterized through the following qualities:

Experiential Qualities of Communication with Digital Materials

From the interrelations between the materials, competence, and meanings analyzed here, the following set of experiential qualities emerges characterizing how communicating with digital platforms is experienced by the teachers:

Effective communication refers to the teachers' perception that because the teaching material is digitalized and persistent and available everywhere and all the time, it will be accessed, read and understood by the learners.

Evidence-based communication. The assessment of the learners' assignments has never been so rationally managed and linked to tangible evidence made available on the LMS. Functionalities such as the subject matrix, for instance, provide a summative representation of the learner's performance and progression that plays a main role in the communication between the teacher and the learner. In particular, the assessment performed defines a dialogue structured around whether the learning criteria are fulfilled or not, the type of feedback provided, the kinds of actions undertaken, and the quality of the recommendations made. Such a structured dialogue contributes to a sense of efficiency and professionalism in the teacher–learner exchange.

Liberated from time and space communication. Putting teaching material into the digital format contributes to expanding the classroom conversation beyond space and time. The digital condition gives the teaching materials a new agency in the teacher–learner communication. Such new status of the teaching material has implications for both teaching and learning. On the one hand, the teachers' assumption that the learners get access to the teaching content before, during, and after the lesson causes them to distribute their time and attention during face-to-face lessons differently, as they can also focus on those students who are curious to know more about the subject. On the other hand, making the teaching material accessible 24/7 on the LMS means that the learners have fewer excuses, for instance, to not turn in an assignment on time. The responsibility for the learners' learning is shared; learners have become responsible for their own learning.

Discussion

The scrutiny of teaching with digital technologies in the school led us to discuss two emergent practices in the school, namely teachers' experimentation with the digital material, which certainly characterizes this first phase of tool appropriation, and teachers' managerial communication practice, which is putting down roots in the world of elementary education. These two practices bring about changes at different levels.

First, and following Levy (1986), I situate the teachers' experimental practice with digital materials as a first-order change. Such an ongoing experimentation can be understood as an incremental change that is reflected in the types of qualities identified; the teaching with digital technology becomes visible, problem-solving oriented and adaptive. However, as was mentioned by the teachers, the use of digital materials does not necessarily revolutionize their pedagogy. This become clear regarding the indifference vis-à-vis the new agency gained by the digital technology in-use and by the learners in the classroom. Here I mostly refer to situations such as for instance a lesson that cannot progress because of a technical problem, or situations where the learners teach the school teacher how to handle a problem concerning the use of an app or other technological matter in the classroom. These situations clearly show new configurations within established relations between teachers, learners, and technology. These new configurations engender changes, for instance in the distribution of the roles and power in the classroom. In the cases studied here, the teachers adjust to the new material arrangements by developing a visible, problem-solving and adaptive teaching without necessarily full engaging with changes regarding the new agency of digital materials and learners in the digital age. These incremental changes can be also understood as a form of resistance to more radical changes that might question teachers' central role in the current educational system. This can also be understood as part of an organic development wherein new material conditions gradually become enmeshed in established teaching practices. Having said that, these changes, which are incremental in nature, might also become instrumental for second order changes, which could eventually compromise the foundations of the didactical contract (Brousseau, 1990). Here, I get back to the role of the technically savvy learner who teaches the teacher how to use the digital material in the classroom, and in doing so, a new organization of the roles and distribution of power can potentially arise in the school. Another instance is the adaptive character of teaching and learning, which puts responsibility on the learner to take command of her own learning; such a development potentially puts learners in a position in which "they are expected to become industrious self-improvers, driven by external goals and striving to improve one own's performance" (Castaneda & Selwyn, 2018, p. 5).

Second, I understand the teachers' managerial communication practice as a second-order change that configures communication as effective, evidence-based, and liberated from time and space. Such a communication practice within the teacher–learner relationship involves a nonlinear progression that is transformational in nature. More precisely, I refer here to new values, such as school effectiveness and customer service practices, which underpin the design of LMS. Surprisingly these changes in the teacher-learner communication do not seem to be resisted in any active way. Conversely, the teachers find this type of communication professional, transparent and modern. They do not actively question the fact that when put into use they shape a communication that "gets entangled in algorithmically engineered digital methods" (cf. Van Dijck, 2011, p. 6). As Orlikowski and Scott (2015) alerted us, the digital material is an active mediator in which entities are themselves entangled. They are not passive mediators or neutral channels but engage actors in enactments of interactional creation of value. On this note, Biesta (2009) highlighted that although it is always sensible to use factual information when making decisions about what ought to be done, such as those involved in the LMS vis-à-vis assessments,

> what ought to be done can never be logically derived from what is (…) we always need to complement factual information with views about what is desirable. We need, in other words, to evaluate the data and for this, as has been known for a long time in the field of educational evaluation, we need to engage with values. (p. 3)

Third, such incremental changes and radical transformations point out that a lens on school practices and their material conditions contributes to a shift from an exclusive focus on the effects of digital technologies on learning toward other aspects, such as the social, value-laden and organizational aspects, which are also constitutive of school practices, school knowledge and learning. On this line of thinking, Biesta (2009) critically evaluated the continual exposition of presentations of educational technologies through a lens on learning and alerted us about the implications of approaching complex and multifaceted educational challenges from mono-dimensional perspectives. Likewise, Castaneda and Selwyn (2018) expressed their surprise via-à-vis the many academic and nonacademic discussions about educational technology that do not inquire about how learning actually takes place and how it is shaped by digital material. As such, these authors highlighted the necessity of developing narratives that "go beyond conceptualizing digital technology as an instrument within instructional design" (Castaneda & Selwyn, 2018, p. 4) and called for discussions about the educational element of educational technology that is not simply common-sense or implicit. Moreover, Castaneda and Selwyn (2018) noted that

> much work in the field continues to conceptualize education as a collection of expertise and demonstrable abilities. In contrast, cultural, affective, spiritual, emotional and ecological aspects are either assumed to be overcome through hyper-rationalist forms of digital education or else somehow controlled and reprogrammable. All of these perspectives work to denaturalize technology-based education [and] deny that it remains a human endeavor shaped by basic human characteristics. (p. 1)

Finally, a lens on practices contributes to understanding that technologies in schools, alter much more than the learners' performance and the teachers' efficiency. They alter the relations and dynamics of assemblages of humans and materials that via the development of school practices configure learning, teaching and school knowledge in new ways. In particular, a focus on the experiential qualities of school practices helps us specify these new configurations that ultimately reflect what changes with the use of digital technologies in the classroom. Yet, the imbrication of technologies in the flow of everyday school practices needs to be better acknowledged, so that conditions favoring deeper understandings of how teaching and learning unfold and transform are redefined (Säljö, 2010; see Saljö's Chap. 2 in this volume). I believe much is still to be done in this direction.

Conclusion

By studying the ongoing digitalization of schools in Sweden, this chapter unpacks the socio-material teaching practices that unfold within the flow of the everyday classroom. The study identifies two main emergent teaching practices, namely the teachers' experimentation with digital materials in the classroom and the managerial communication practices bound to the use of the LMS in schools. Such practices present experiential qualities that speak of teaching that is becoming visible, problem-solving oriented and adaptive, which is also effective, evidence-based and liberated from time and space communication. It is in this context that it is argued here that while the teachers' experimentation with technologies represents incremental changes in their teaching practice, the emergent managerial communication seems to challenge the cultures and ethos of Nordic schools. The chapter contributes to renewing interest in the practice approach to studies of technology in education.

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Chapter 4
Exploring Representations of Classroom Practices Mediated by Information Communication Technologies (ICTs)

Mariana Landau

Abstract This is an exploratory study which aims to identify analytical dimensions that allow understanding the representations of classroom practices mediated by ICTs in the images of school classes presented in the articles of the written press. Sociomaterial and Multimodal perspective categories are recovered to understand the regularities and the differences in the meanings that these images construct even in different countries. This study contributes to a deeper understanding of the scenes, the actors (students, teachers), the forms of interaction and the artifacts that are privileged in the media discourse about ICTs in schools developed in South America. In the analysis of the learning events with ICTs that are represented in written press we can find some relation patterns in which the notebook is part.

Keywords ICT · Mass media · ICT policies in education · Digital education · Learning · Netbooks · Multimodality · Materiality

Introduction

When speaking about schooling, one of the first mental images that appears to those who have gone through the school system is the classroom. That is, the idea of the classroom is closely linked to representations about schooling, at least in Latin America.

Dussel and Caruso (1999) make a historical journey about the genealogy of the classroom. They consider that the popularization of the classroom in relation to schooling materializes with the consolidation of pedagogical methods that promote the organization of teaching by differentiated school groups. The classification criterion of these groups in some cases is age and in others it is performance. In addition, they argue that the analysis of the classroom in terms of driving is strongly articulated to the power relations in society as a whole.

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The classroom did not always exist as a concept or space for the cultural transmission of the literacy. It is the fruit of a construction that begins to be outlined at the end of the Middle Ages; such development was strongly influenced by clerical traditions (confessionals and preaching, among others).

The present forms of organization of communication in the classroom practices and policy discourse are in tension between two poles (Guerrero & Kalman, 2010; Sardi, 2017). On the one hand, a model centered on the teacher, who appears as a source of knowledge and the one who monopolizes the word through his speech; it constitutes a transmision model in which the accumulation of knowledge is central. In this transmision model also called broadcasting model the blackboard has an anchoring function of the teacher's voice and with a special configuration of space with different regions (Sorensen, 2007). However, this broadcasting communication organization model in the classroom is not only an instance of the past but also of the artifacts such as the chalk and the blackboard that today seem to be replaced by the mobile screens and more recently by the inclusion of interactive whiteboards in the classroom. On the other hand, the classroom can be configured as a space for inquiry in which what is central are the learning processes that are possible to unfold. In this model called collaborative or interdisciplinary, the role of the teacher is understood as a guide or coordinator rather than as a privileged enunciator of knowledge.

The study of mediated interactions within the educational system includes considering the inclusion of new technological artifacts, but also the discourses that alter the canonical forms of classroom exchange and the ways in which what constitutes educational content is defined. From a multimodal perspective, Bezemer, Jewitt, Diamantopoulou, Kress, and Mavers (2012) have analyzed the transformations in teaching, comparing an English class of year 2000 and another of the year 2006 dictated by the same professor. In the class year 2000 the teacher uses the overhead projector, in the class year 2006 the teacher uses the interactive whiteboard (IWB). Both classes focused on the same curricular category namely, poetry. However, both the semiotic landscape and the possibilities of participation from the students' side have differed significantly. Likewise digital technologies configure the ways in which society builds and provides access to shared memory repositories. Technologies do not improve learning in a linear way but significantly alter the ways in which people understand what to learn means and what implies that a person possesses knowledge about a topic (Säljö, 2010).

Situated within such conceptual context, in this chapter I analyze everyday educational practices that are shown in the written media images in Argentina and Uruguay. More specifically, these images were taken from articles reporting on the latest state initiatives conducted to introduce ICTs in the education system.

Through this perspective, it is possible to approach the *discourse* that media condenses and puts into circulation in different spheres of society. This type of representations is related with the common sense that crosses the different social actors in general and the members of the educational communities in particular. The chapter builds on a broader research project that entails addressing the study of the consequences involving partnerships between state policies, technology companies, and media groups in education.[1]

Historical Route of Technology in Schools in Latin America

The first educational national public policies on ICTs in Latin America were deployed towards the end of the 1980s and the beginning of the 1990s (Landau, 2002). In Argentina, little by little the integration of digital technologies in the classroom was increasingly crossed by the explicit actions developed both from the national state and from the provincial administrations. Policies for the introduction of technologies in the education system were immersed in a process of general education reform that began in the 1990s.

Moreover, for some authors, the policies of integration of digital technologies in the education system constitute the last stage of a series of top-down reforms. That is, these reforms are conceived and designed in a central way, in which the schools constitute the space of application of these policies. In this context, the evaluation of the programs is aimed at measuring the degree of correspondence between what was designed by the educational administration and what was implemented in schools (Dussel, 2014).

In the 1990s, with the generalization of utilities and office packages, the spectrum of possibilities and demands on the system was broadened with respect to students' use and knowledge of digital technologies. With graphical interfaces, the friendliness of environments expands. Technologies were called to be incorporated into the curriculum as transversal content. Discourses placed ICTs as a "tool" and as "motivation" for learning to expand (Goodson & Mangan, 1996). It is in this same decade (1990s) that I can place the first lines of national policy in Argentina on the introduction of ICTs. First, technologies in schools were promoted as short-term focused policies, some of which had international financing (Plan Social Educativo and PRODYMES, among others). Moreover, technology was incorporated as content to be taught in the curricular designs that were reformulated after the establishment of the Common Basic Contents (CBC). In the year 2000, Argentina implemented the first national initiative to equip schools with technology, develop educational content and train teachers. With the launch of the Educ.ar portal, the proposal that contemplated the possibility that all the students could access to a computer at school was presented through a loan that was to be awarded by an International funding agency for this purpose. With the economic crisis that the country went through at the end of 2001, this project was suspended and only the educational website has been continued until today.

[1] This chapter is included in the research UBACyT 20020150200214BA "Mediated Educational practices in public discourse in Argentina." The project is directed by Mariana Landau, and it is financed by University of Buenos Aires, Argentina.

Parallel to the new Argentine policies, technologies continued to increase their presence in society. With the expansion of Internet and networks (Wifi/WLAN), computers ceased to be individual to become personal communication devices. Technologies were used for building learning communities and pondering collaborative learning. The first experiences that used e-mail as a means of communication and the web as a tool for accessing information are enriched by the transformations of Web 2.0 (Jahnke & Koch, 2009; Jahnke & Kommers, 2009), which expanded the possibilities of content production, giving rise to the desire to train "prosumers." This term was constituted as a metaphor of the desired activity for the students, configuring itself as an antagonistic metaphor to the positions expected in the origins of the educational system in which the passivity and the reception were the privileged activities that crystallized in the metaphor of the "Banking education" proposed the greatest exponent of the Latin American critical pedagogy, Paulo Freire.

In April 2010, *Conectar Igualdad* (Connect Equality) was founded (it is worth paying attention to the name of the program) and aimed at recovering the prominence and relevance of public education and the inclusion of all young people in the education system. This center established an important shift in the perspectives that had accompanied the inclusion of technologies from the mid-1980s to the middle of the first decade of the twenty-first century, guided by economic liberalization and the association between the demands of the labor market and the school. In this universal policy framework, ICTs were presented as an inclusion agent aimed at ensuring the rights of citizens (Presidential Decree 459/2010).

In December 2014, the delivery of 4,700,000 netbooks was announced. With this amount it was ensured that all students and teachers of public secondary schools in the country have a netbook. This act would imply, in the words of the then president of Argentina, Cristina Fernández de Kirchner that "we have covered the digital divide."

Nowadays, with the ubiquity of technologies in different spheres of society, and with the emergence of cell phones as a unifying device for personal life (Winocur, 2009), technologies in the education system acquire new ways of integration like Bring Your Own Device (BYOD) initiatives (Landau, 2018). Despite these possibilities the map of the mobile devices is not uniform: the localization of the technologies is regulated sometimes by the school and sometimes by the educational administration.

Specificities of One-to-One Model ICTs Policies in Education in Latin America

In the last decades, the initiatives of the one-to-one model have acquired an important significance even in governments of different political sign in Latin America.

While in some countries such as Bolivia, Colombia and Ecuador small-scale policies were designed, Argentina and Uruguay have developed universal lines of action in which the national State has played a central role. The first country that implemented this type of policies is Uruguay with the launch of the Ceibal (*Plan de Conectividad Educativa de Informática Básica para el Aprendizaje en Línea* or Computer Educational Connectivity Plan Basic for Online Learning) in April 2007. This Plan in its early days focused on providing equipment, connectivity, and educational resources to all primary schools in Uruguay.

Three years later, in 2010, Argentina began its ICTs integration policy (a 1:1 program) for the secondary level, the Institutes for Teacher Training and the special education schools called Conectar Igualdad (Connecting Equality). Through this social and inclusive strategy, it was expected to provide a digital device to each student, train teachers and produce educational materials for use in the classroom. In parallel, an operating system was developed in Linux, Huayra, available to schools that would like to get started on the paths of open source software.

In short, Conectar Igualdad and Ceibal are two programs that share being universal policies, that is, they have distributed equipment to all the educational levels that they attend. Both plans have similarities and differences:

The programs, Conectar Igualdad and Ceibal share the following similarities:

- Socio-economic and political context. During the beginning of the millennium Argentina and Uruguay went through very deep economic crisis that includes devaluation, fiscal adjustment and unemployment, among other negative things for the citizens. This economic crisis derived a few years later in an important change in the political map. In Argentina, in 2003, the “kirchnerismo” (Kirchnerism) the left of the Peronism, that some author considers a new populism and others described them as postneoliberal, won the elections. In Uruguay, in 2005, the “Frente Amplio” (Board Front) a coalition of left parties assumed the government for the first time. These parties positioned themselves in a perspective that emphasizes the citizen rights and the development of the country with social justice.
- Management strategy. Both Ceibal and Conectar Igualdad were managed by several public organisms. In Argentina, Conectar Igualdad was conducted by Ministry of Education, Social Security National Administration (ANSES), Ministry of Federal Planning, Public Investment and Services and Chief of Cabinet of Ministers. In the case of Uruguay, CEIBAL, that in the beginning was a project and it derived in a plan, has been managed by a commission conducted by a delegate of the Presidency and integrated by one delegate from each of these organisms: National Administration of Public Education; Council of Primary Education; Ministry of Education and Culture; Technological Laboratory of Uruguay, National Telecommunications Administration, Agency for the Development of Electronic Government and the Information Society; Innovation Agency (Article N 2 of the Decree 144/07). Then other organisms were included.

- The relationship with educational policy. Both countries include in their national educational laws the priority for including ICTs in the educational system (Ley de Educación Nacional N° 26.206 of 2006 for Argentina y Ley General de Educación N° 18.437 of 2008 for Uruguay).

The programs differ in the following aspects:

- The political organization. Argentina is a federal country; most of the educational initiatives must be arranged with the provinces (that are a kind of state). Uruguay is unitary and smaller than Argentina that implies a central organization and administration.
- The educational levels covered. In the beginning, Ceibal has begun its action in primary school[2] and Conectar Igualdad was oriented mainly to the Secondary School.
- The type of hardware that was distributed. While Ceibal distributed the OLPC XO (One Laptop per Child), Conectar Igualdad acquired several brands of netbooks.
- The evaluations carried out by these programs on the One-to-One policies implemented in these countries. Critical reports in Uruguay were built on tools to reformulate lines of action; in the case of Argentina, especially government agencies "felt the burden of building legitimacy for programs, which is evident both in the way research is produced and in the communication of its results" (Dussel, 2016, p. 152).
- Finally, the program's directions. At the time of writing this chapter, Ceibal is a current policy that has expanded its influence to the secondary level, among other aspects; while the continuity of Conectar Igualdad is uncertain, after important dismissals of staff and slow down for a prolonged period of time to almost inaction of the delivery of equipment, the Plan remains in force in the institutional organization chart but without the prominence of the one enjoyed until 2015.

With regard to the forms of representation in the written press of each of the programs, both programs at the beginning enjoyed express support for the initiative to provide equipment, connectivity and content to the education system. In the case of Uruguayan policies, the arrival of computers was linked to progress, social development, equal access and the achievement of skills related to digital culture (Winocur & Sánchez Vilella, 2013).

In the case of Argentina, this acceptance and need for the policy was also present and the differences emerged in relation to the implementation. The positioning of the written press on Conectar Igualdad reproduced the confrontations between the media and the executive power that were resent during the last years of the Kirchner's government (Landau, 2015).

[2] The Secondary School was included in Ceibal in 2008.

Methodology

The study is framed within a paradigm of qualitative research. It is an exploratory study which aims to identify analytical dimensions that allow for understanding the representations of classroom mediated by ICTs in the newspaper. To do this, I used several theoretical perspectives:

First of all, the material learning perspective allows for understanding the place of the objects in a relational view (Cerratto Pargman, Knutsson, & Karlström, 2015). This perspective is associated with several scholars such as Latour with his actor–network theory and is very close to the sociocultural perspective (Engeström, 2001).

> in order to grasp the materiality of learning, we must describe a particular learning practice as a pattern of relations of human and nonhuman components, and we must characterize the way in which humans are present in this practice (Sorensen, 2009, p. 176)

Second, multimodal perspective categories are recovered to situate characterization of meaning regulated by the social and the cultural aspect. The semiotic system presents different possibilities of classification and ordering of social life, and it is the speaker (individual or institutional) who chooses the contents of his message within the possibilities of the language and the social practice in which it is registered.

Both written text and visual communication are seen as cultural constructions. Both can be used to convey the same meanings, however, each one does so by means of its own forms and it does so in a different and independent way. In turn, each medium presents its possibilities and limitations.

> Visual structures do not simply reproduce the structures of 'reality'. On the contrary, they produce images of reality which are bound up with the interests of the social institutions within which the images are produced, circulated and read. They are ideological. Visual structures are never merely formal: they have a deeply important semantic dimension. (Kress & van Leeuwen, 2006, p. 47).

From social semiotics, it is considered that every text is composed of three types of meanings: (a) the experiential, which encodes our experiences of the world; (b) interpersonal, which allows us to interact with other(s); and (c) the textual ones, which organize the experiential and the interpersonal to form messages that are relevant and coherent with the textual practice and the context of the situation. This tripartite vision is recovered because it functions as a good basis for understanding the different modes of representation.

These analytical dimensions are reformulated to account for the forms of construction of meaning in visual communication. In our case, in the ideational metafunction we study the actors, the processes, and the circumstances in the illustrations with narrative content. In this case we retrieve the vectors that can be translated as action verbs "the child looks at the computer," "the teacher explains to his students."

For the interpersonal dimension, the frame and the angle of the shot are recovered, in addition to the degree of detail. Finally, the textual metafunction takes the notability of the elements that are marked above all by its relative dimension and its position. The interpretive activity starts from the most remarkable point (Morales & Lischinsky, 2008).

With these conceptual tools, in this chapter, I present the representations that the written press builds and shares about learning spaces and technologies related to the national policies that were implemented in Argentina and Uruguay during the last decade.

Findings: How the Written Press Constructs/Shares Universal Policies of Inclusion of ICTs in the Educational System in Argentina

To analyze how the representation of the learning events with ICT in the public sphere is, in this chapter, I took a corpus integrated by the images that are in the articles of the newspapers with a very important tradition and history from Argentina and Uruguay related to ICTs national policies in education.

I selected La Nación (www.lanacion.com.ar) from Argentina and El País (www.elpais.com.uy) from Uruguay. In this approach I observed that many texts do not contain images.[3] In cases where there is presence of illustrations, most of them are naturalistic images like photographs. Two types of representations are distinguished: (a) objects, basically of computers[4] and; (b) of people. With regard to the images that reflect people, it is possible to divide them into two types: those that contain adults who do not participate in school daily life, for example, government officials, experts and consultants, usually males[5]; and articles that show photographs of children and young people, often in class situations, interacting with portable devices.

The senses of the images are often constructed in articulation with the written text but in many other cases there is no correspondence, marking a certain autonomy in this way to signify. For example, in "(Dis) Connect Equality: a program that inspired praise, but today receives criticism"[6] the article refers to the role of teachers

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[3] https://www.lanacion.com.ar/1979489-plan-conectar-compraran-450000-netbooks and https://www.elpais.com.uy/informacion/ceibal-decada-plan-equidad.html, among others.

[4] With respect to the presence of computers, it is important to note that at least in Argentina, the distribution of these low-cost portable devices was the most important component of these policies that based a large part of their initiatives on the idea that Access to these technologies would favor the end of the digital divide.

[5] https://www.lanacion.com.ar/1800650-alejandro-artopoulos-el-programa-conectar-igualdad-fue-un-fracaso and https://www.elpais.com.uy/informacion/experto-insto-cambiar-pedagogias-acelerar-logros-plan-ceibal.html and others.

[6] https://www.lanacion.com.ar/1757467-desconectar-igualdad-un-programa-que-inspiro-elogios-pero-hoy-recibe-criticas.

in the pedagogical use of digital technologies and the image too. In contrast, in "Plan Ceibal arrives at Paraguayan school"[7] the image does not reflect the contents of the article. In this line, it is significant to analyze the other senses that the visual semiotic mode builds by itself.

The scene of children and young people interacting with portable devices distributed by ICTs integration programs in the education system is the most predominant when it relates to young audiences and schools. This image acquires centrality because the human figure becomes the focal point of attention in any space and because it contains the participants of the actions that "play the most crucial roles in the grammatical structure that constitute the meaning of the picture" (Kress & van Leeuwen, 2006, p. 50). This scene constitutes a cultural environment that is encoded as a recognizable unit.

However, beyond this regularity, it is possible to point out differences in relation to the participants and the angle of taking the photograph. These aspects are recovered to account for the meanings based on the meta-functions specified in the methodological section.

The first type of images, present in both newspapers, corresponds to *photographs that contain a scene with a student alone with his or her computer*.

In the case of Argentina, we find in the article "The Connect Equality plan follows, affirm in the Ministry of Education"[8] a scene of a single girl interacting with her digital device. However, one of the peculiarities of this image is that the girl in addition to her netbook has a copybook in her hand.[9] The observer is facing away from the girl. It is possible to draw a vector that reproduced the look of the girl: this would go from the eyes of the girl to the copybook and the netbook that are almost equal, although the copybook is located slightly higher than the digital device. Also, the girl's gaze is more oriented towards the copybook than towards the computer. This image of the use of technologies is consistent with the definitions of digital literacy that emphasizes the difference between digital information media and print media (Lankshear & Knobel, 2006).

In the case of Uruguay, I recovered three articles. In "The IDB Loan to Strengthen Plan Ceibal"[10] it is possible to see the image of a female student who wears her white apron[11] and uses an XO computer. That is, this image shows the conventional attributes of the public school and Plan Ceibal. In the epigraph, which is embedded in the photograph, it reads: "The Plan Ceibal was an 'insigna ship' of the first

[7] https://www.elpais.com.uy/informacion/plan-ceibal-llega-escuela-paraguaya.html. This article is about an Uruguayan school in Paraguayan territory.

[8] https://www.lanacion.com.ar/1876751-el-plan-conectar-igualdad-sigue-afirman-en-el-ministerio-de-educacion.

[9] The copybook is an element that is used in primary education, and Connect Equality is a plan intended for secondary schools. In the body of the note, there are references to "Digital Primary." So it is probable that this image is linked to this program.

[10] https://www.elpais.com.uy/informacion/prestamo-bid-potenciar-plan-ceibal.html.

[11] This clothing is called "túnica" and with the "moña" they are the symbols of the public Primary school in Uruguay.

Vázquez government." The legend or epigraph included in the image provides reading guides about the image. The metaphor "insignia ship" emphasizes the significance of Plan Ceibal in the government strategy. The observer of this image is positioned with his back to the girl. In this way the centrality is located in the portable device that faces the observer. This device works as synecdoche of Ceibal Plan; and the Ceibal Plan works as a synecdoche of government policy.

In the article 'the World Bank acknowledged that it was wrong to describe Plan Ceibal as "ineffective"'[12]; a female student with a computer can be observed again, although a very small part of another boy's body appears. The girl in the central scene is without the uniform, that is, it is an image that could be placed outside the school setting. Here also the centrality is given by the portable device. In this situation, the angle of capture marks a very clear asymmetry that places the observer in a place of power. The use of the high-angle shot locates the observer above the scene. This view is consistent with the title that highlights who is the legitimate actor that can evaluate the significance of the Plan.

The image of the article "Plan Ceibal arrives at Paraguayan school"[7] placed it in this category because beyond presenting several children with their computers, a single male student stands out and the rest are out of focus. In this image, unlike those described above, the centrality is in the child and not in the computer. In addition, this child facing the camera does not look at the computer but at the source of light that seems to come from a window.

The second type of image corresponds to photographs of children and young people interacting with their portable devices on school grounds and in which a teacher appears. In this category I found an image in La Nación and another in El País.

In "(Dis) Connect Equality: a program that inspired praise, but today receives criticism"[6] the image reflects three students and a male teacher in class situation. In the background, the chalkboard is written with class slogans. The students are on their backs interacting with their netbooks and the front teacher who looks at one of the screens but who corporally addresses everyone. This illustration also presents an epigraph that anchors the senses of photography when placing the professor in a leading position. He is the subject of sentence and the agent of the action: In class. Professor Palma looks for implementing a work plan to take advantage of the full potential of his school hour and established concrete guidelines on working in class with netbooks.

In "Emotions are also a matter of Plan Ceibal"[13] there are seven students dressed in their white apron and with an XO in each of the desks. In the background there is a female teacher, whose head does not appear complete, but lets us assume that her eyes are directed towards the students. Two of the students in the background, who appear smaller and less clearly, look at the teacher. Meanwhile, students who excel, to be closer to the camera, focus their eyes on their portable devices.

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[12] https://www.elpais.com.uy/informacion/banco-mundial-reconocio-equivoco-calificar-ineficaz-plan-ceibal.html.

[13] https://www.elpais.com.uy/informacion/emociones-son-asunto-plan-ceibal.html.

From this first description it is possible to enunciate some interpretative categories that would make it possible to approach the analysis of these images given the regularity observed, at least, in the analyzed images. These dimensions could be outlined as tensions between:

1. One student only and many students
2. Students looking at the device and student looking elsewhere
3. Student's point of view and other point of view
4. Absence and presence of teacher
5. Teacher centrality and non-centrality
6. Presence and absence of prototypical elements of the school scenario (e.g. blackboard, copybook)
7. Presence and absence of prototypical elements of clothing school (apron)

The spatial location of educational scenes constitutes a substantive aspect in the analysis of the materiality of teaching. In many of the images analyzed, the classroom continues to be a privileged stage of representation. However, this location is not the only possible one.

The images of the newspapers highlight the central scene of a boy or a girl in front of the netbooks delivered by the ICTs integration program of reference. However, beyond this regularity, it is possible to identify different materialities depending on the other artifacts and people that make up the scene.

Discussions and Implications: The Interaction in the Classroom

This exploratory study presents several topics about the course of schooling, and especially with the representations of classrooms mediated by ICTs in written media press.

First, the analysis shows that the computers have a central place in the written press articles about national policy of ICTs. The images of computers are present in several images, alone or with persons. This emphasis can be related to the accent that these policies had in the distribution of personal devices at least at its beginning of its creation. But also, this type of representation can allow to think that digital literacy can be solve only with interaction, or at least, with the possession of the computer.

In this sense it is important to make a difference between a distribution of equipment national policy and an educational policy. Sometimes those two types of initiatives are overlapping, both in the government and in media press. This simplification hides the complexity of teaching and learning in new environments, reading and writing through the new media and modes of representing and the variety of legitimate knowledge sources that currently circulates at schools, in other aspects.

Second, it is important to highlight that the image of learning that shows a student alone with a computer is frequent. This type of representation implies a new step in the historical development of the classroom and enables a semiotic landscape about the shapes that can assume the learning events.

Third, the presence or the absence of some actors, like teachers or other students, can acquire different values. These points of view can be sawn by analyzing the vectors and the angle of camera shot. I find that the line that traces the gaze can show differences with the implication with the monolithic images that show a student alone with his/her computer.

Fourth, the image of a student studying alone was not a content of the written text. That additional meaning was carried only by the visual communication mode. In methodological terms this article emphasis to the necessity of developing new studies with sociomaterial and discourse analysis perspective.

By last, the images of written press show some representations and hide others. The images of the press show scenes easily recognizable by the reader. These scenes are based on a recognizable image and are anchored in some of the classic elements of the school scene (blackboard, clothing, notebook, among others) and technologies (netbook, XO devices). However, in the material conditions in which mediated learning is carried out, it includes other devices such as cell phones, applications, programming, robotics, which the images selected at the moment, do not manage to capture. It will be necessary to develop new studies that reveal the presence or not of other formats of learning organization.

Limitations of the Study

This study is exploratory so I can't generalize the findings. They only bring some guides for future researches and illuminate the significance of the written press in general, and particularly the images that are included in this articles related with the images of classroom.

In terms of conceptual terms, the time is absent in this analysis. The time is a very important aspect of the socio material learning practices and it is possible to include it only with other kinds of information gathering instruments.

Conclusion and Outlook

The classroom is a historical construction that is currently under tension. In the narration of the implementation of the national ICTs policies the written media press adds and reproduces new senses about the shapes that assume the organization of the schooling nowadays.

In this way, it is important to develop new studies that show (a) what the continuities and ruptures between the image of documents of the national policies and written media press are, (b) how the representation of classroom in each newspaper is, and (c) if there are similarities and differences in the representation of the classroom between the newspapers that have different political positions.

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Part II
Understanding Emergent School Practices and Their Inherent Materiality

Chapter 5
Conditions for Teaching with Mobile Technology in the School Classroom

Marcia Håkansson Lindqvist

Abstract The uptake and use of mobile technology in the classroom and the conditions for teaching with mobile technology were studied in the research project Unos Umeå in Sweden from the student, teacher, and school leader perspectives. A 1:1 laptop initiative was studied in two schools over a period of 3 years. The aim of this chapter is to explore, analyze, and discuss the conditions for teaching, as possibilities and challenges, in the final phase of this initiative from the teacher perspective. Teachers saw possibilities in teaching through information, communication, and structure, noting the importance of pedagogical reflection and design. The challenges were technical problems, student use of the laptop, and time for and access to professional development. Teachers focused on helping students see the laptop as a school tool as well as taking on a new tool in the classroom, that is, the mobile phone.

Introduction

The expectations of society regarding teachers' uptake and use of mobile technology, such as laptop computers, tablets, and mobile phones, in the classroom and the conditions for Technology Enhanced Learning (TEL) are high. The intentions put forward in policy (EC, 2010; Eurydice, 2012; OECD, 2012) comprise hopes for enhancing learning outcomes and student engagement, as well as more efficient administration and organization of learning. However, the actual impact in practice appears to involve challenges (cf. Kirkwood & Price, 2013, 2014; Olofsson, Lindberg, Fransson, & Hauge, 2011; Olofsson, Lindberg, & Hauge, 2014; Tondeur, Forkosh-Baruch, Prestridge, Albion, & Edirisinghe, 2016; Voogt, Erstad, Dede, & Mishra, 2013). Teachers, according to Hixon and Buckenmeyer (2009), often receive the blame for not integrating technology in their teaching, with reasons such as lack of time, training, equipment, and support. Although research on Information

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and Communication Technology (ICT) in education points toward teachers gradually beginning to integrate ICT into their teaching, significant differences can be observed in how ICT is integrated in the K–12 classroom (cf. Bocconi, Kampylis, & Punie, 2013; Tondeur, Cooper, & Newhouse, 2010). This may reflect differences in how teachers consider the uptake and use of mobile technology in relation to didactical design (cf. Jahnke & Kumar, 2014; Jahnke, Svendsen, Johansen, & Zander, 2014; Olofsson & Lindberg, 2014; Selander, 2009) or orchestration (cf. Hauge, 2014; Öman & Svensson, 2015; Perrotta & Evans, 2013) for enhancing student outcomes and creating conditions for TEL.

It appears that successful technology integration requires more than just having access to computers in classroom. Deployment is not enough, according to Warschauer, Zheng, Niiya, Cotten, and Farkas (2014), and there is the need to address the many challenges which have impact on teachers' decisions regarding the uptake and use of mobile technology in the classroom. Mandating teachers' uptake and use of mobile technology does not appear to be sustainable. A more fruitful approach, according to Yeung, Taylor, Hui, Lam-Chiang, and Low (2012), may be to enhance the competence of teachers in mobile technology by helping them to see the value of the effectiveness of technologies and thus gain confidence in applying these in practice in their teaching activities. This also goes beyond using the laptop as an administrative tool (cf. Halverson & Smith, 2009). The act of both balancing analog and digital communication as well as intertwining these types of communication in the classroom may even prove to present new environments in the form of CrossActionSpaces (Jahnke, 2016).

Teachers' use of ICT and their skills appear to be related (Sipilä, 2014). When studying teachers' strong technology practices in K–12 classrooms, Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, and Sendurur (2012) found a close alignment between teachers' beliefs about student-centered beliefs and student-centered practices such as authenticity, student choice, and collaboration. According to Drayton, Falk, Stroud, Hobbs, and Hammerman (2010), teachers need teacher professional development (TPD) as well as time to discuss content, students' work, pedagogy, and technology. Ertmer and Ottenbreit-Leftwich (2013) report that teachers' activities regarding the uptake and use of mobile technology in schools and the shift from technology to pedagogy takes time. It is also important that teachers believe in their own abilities and work in a school culture that sustains a type of TPD, which combines technical, pedagogical, and subject-related didactic competences (Ertmer & Ottenbreit-Leftwich, 2010; Kopcha, 2012; Mishra & Koehler, 2006; Voogt, Knezek, Cox, Knezek, & Brummelhuis, 2013). Towndrow and Wan (2012) emphasize the importance of teachers' collaboration through seeking and sharing, and according to Vrasidas (2015), for TPD to have impact, it should be collaborative and situated in teachers' everyday practice.

The aim of this chapter is to explore, analyze, and discuss the conditions for teaching, as possibilities and challenges, related to the uptake and use of mobile technology in the classroom. This aim hopes to provide new knowledge regarding the conditions for TEL from the teacher perspective in the final phase of a 1:1 laptop initiative in two schools in Sweden. This chapter seeks to examine how teachers' perspectives related to the uptake and use of mobile technology in teaching activities developed over time. The following research questions are posed: (1) *How can the uptake and use of mobile technology in the classroom in teaching activities be described and related to the conditions for TEL?* and (2) *How can the possibilities and challenges in the development of the uptake and use of mobile technology in teaching activities over time be understood as conditions for TEL?* This chapter aspires to contribute to the research areas of 1:1 and TEL from the teacher perspective, as well as contributing to insight in emergent practices and material conditions in teaching and learning with mobile technology.

Overview of Research Studies on the Integration of ICT in Schools

Internationally, the uptake and use of mobile technology through one to one (1:1) involving one laptop per student continues to increase, even being described as a tsunami (cf. Livingston, 2007). This has also been the case in Sweden, where access to laptops in schools is considered to be good (National Agency for Education, 2013a, 2016). However, the laptops are not used to the extent as intended in school policy (Swedish Schools Inspectorate, 2011, 2012). In the National Program for School Development, The National Agency for Education (2017) views digitalization as one of eight prioritized areas for supporting students' learning, development, and achievement. In an international perspective, 1:1 initiatives are reported to offer benefits such as equity in access to technology, the quality of instruction, student engagement, academic achievement, digital competence, economic competitiveness, and improved communication between the home and school (Harper & Milman, 2016; Penuel, 2006; Rosen & Beck-Hill, 2012). Despite the increasing number of 1:1 initiatives around the world, there appears to be limited research concerning prevalence, scale, and scope of research initiatives in 1:1 settings (Richardson et al., 2013; Zheng, Warschauer, Lin, & Chang, 2016). While some 1:1 initiatives are reported to be sustainable (Bebell & O'Dwyer, 2010; Penuel, 2006; Silvernail, Pinkham, Wintle, Walker, & Bartlett, 2011), there are also challenges put forth in research (Cuban, 2001, 2013; Hu, 2007). Studies show that results related to laptops in the K–12 classroom may have minimal effects on academic results (Cuban, 2001, 2013). Student achievement may be improved under certain conditions and in different content areas (Dunleavy & Heinecke, 2007). When using the laptop as a school tool, that is, meaningful learning (Jahnke, Bergström, Mårell-Olsson, Häll, & Kumar, 2017), there appears to be potential for transformative added value in the 1:1 classroom (Zheng et al., 2016). Thus, in 1:1 implementations, the focus on if students' academic achievement is improved or not, should perhaps be studied more in terms of "how, why and under what conditions" (Harper & Milman, 2016, s. 140). If teachers see students as receivers of knowledge, learning environments will prevail to be directed by teachers, despite access to 1:1 (Varier et al., 2017). These researchers see values, goals, and pedagogical innovation which optimize technology use as important to successful integration. In addition, integration calls for high-quality TPD (Dunleavy, Dextert, & Heinecke, 2007). While mobile devices such as laptops, tablets, and mobile phones appear to prove potential as learning tools in the classroom (Sung, Chang, & Liu, 2016), teachers, students, and parents do not always agree on the roles of these tools, that is, mobile phones (cf. Gao, Yan, Wei, Liang, & Mo, 2017). Research in 1:1 in the Swedish context appears to be in line with international research (Andersson, Hatakka, Grönlund, & Wiklund, 2014; Fleischer, 2013; Grönlund, 2014; Grönlund, Andersson, & Wiklund, 2014; Tallvid, 2010, 2015) echoing many of the possibilities and challenges reported in the international literature. This chapter will add on to previous studies reported on the conditions for TEL in a 1:1 initiative from the student, teacher, and school leader perspectives (Håkansson Lindqvist, 2013, 2015a, 2015b, 2015c, 2015d). In these studies, teachers saw possibilities in new forms of teaching, sharing materials, and documentation. The challenges were related to students' use of the laptops, motivating students to use the laptop as a school tool as well as time for and access to TPD. In this chapter, the results of the last year, the final phase, will be explored, analyzed, and discussed.

The Ecology of Resources Model

The ecology of resources model (Luckin, 2010) is based on learning as an interaction between the individual and the sociocultural environment (Säljö, 2000, 2005, 2010; Vygotsky, 1978). According to Luckin (2010), the model can be used to design or redesign learning contexts or as a theoretical foundation for improving particular learning contexts or activities. The model illustrates the resources available to the learner as shown in Fig. 5.1.

In the model, the learner is surrounded by the three resource elements, *Environment*, *Knowledge and Skills*, and *Tools and People*. These resources are said to be accessible to the learner, and be accessed both directly and indirectly. If the learner is situated in the central position of this learning activity, demands can be placed on the surrounding environment, context and design (Luckin, 2010). In this chapter, the teacher is in focus as a learner. The use of the ecology of resources model (Luckin, 2010) and the theoretical concept of filters has been fruitful in identifying possibilities and challenges in the development of teachers' perspectives on their teaching activities over time. In this chapter, the use of the model as a tool can be closely linked to understanding the conditions for teaching and learning processes and the relationship between tools and technology as an emergent practice in the classroom (cf. Cerratto Pargman, Jahnke, Damsa, Nussbaum, & Säljö, 2017).

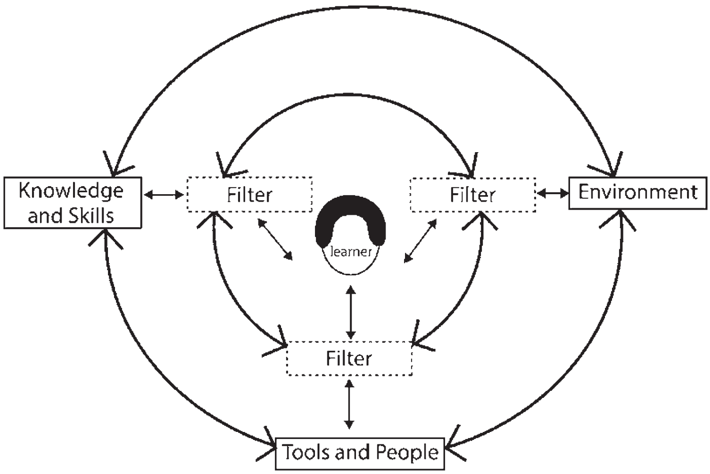

Fig. 5.1 The ecology of resources model (Luckin, 2010). Elements and their filters

Mobile Technology in the Classroom

The research project Unos Umeå studied the uptake and use of mobile technology, laptop computers, in teaching and learning activities from the student, teacher and school leader perspectives, as well as the impact on the schools as organizations in a 1:1 laptop initiative. The empirical base was collected over three phases of a 2-year period of an overall 3-year research project, at two schools in Umeå, Sweden. The Unos Umeå project can be described as a 1:1 case study with a research design involving a case study approach (Simons, 2009; Yin, 2009). All of the studies took place within both schools, in two classes in the compulsory school and two classes in the upper secondary school. Both schools had schools leaders and teachers who had a positive view of technology to support learning. The teachers who participated in the study showed a wide range of use and design for mobile technology in their teaching. While some teachers were hesitant to integrate technology, other teachers integrated the new technologies fully.

Method

The empirical data can be said to be threefold, in an attempt to achieve a more complex form of data material, and thus a wider understanding of the 1:1 initiative in its specific context crosschecking findings (Patton, 2002) and triangulation (Hammersley & Atkinson, 2007). The empirical data in total comprised surveys, interviews, and classroom observations (N = 1370 surveys/39 interviews/126 lessons, 124 h) with teachers, students, and school leaders (Håkansson Lindqvist, 2015a) for the first three phases of the project (P1–P3). The first phase (P1) was the initial phase of the project in the fall of 2011. The second phase (P2) was some 6 months after the start of the project (i.e., spring 2012). The third phase of the projects was 1 year later (i.e., spring 2013). In this final phase, Phase 4 (P4), the data set in focus is the final interviews with the ten teachers ($N = 10$) and the field notes from classroom observations ($N = 49$ lessons, 50 h) in the classes involved the last year and final phase during spring 2014. Both the interviews and the field notes from the observations were coded and categorized using content analysis (Hjerm & Lindgren, 2010).

Results

In this section, the interviews with the teachers (T1–T10) and some notes on the classroom observations are presented, in the following themes: *teachers' laptop use* and *teachers' perspectives on students' laptop use*.

Teachers' Laptop Use

When teachers' expressed their perspectives on their own use, the following themes were discussed: *own use, laptops and other tools, TPD*, and *technical problems*.

Own Use

When teachers reported their own use, they reported several aspects of use. One teacher saw the administrative side of use: "Lots of administration on the side of lessons. Lots and lots, all the time" (T2). Another teacher did not see any specific change in use, but noted that the laptop was always used in teaching: "I use it [the laptop] as I have before. Now, I always have it with med during lessons. I use the active whiteboard a lot" (T8). One teacher also reported new use of the laptop: "I only use the interactive whiteboard now. I didn't do that last year… It is great because you can save everything and send it out to the students" (T6).

Teachers also reported possibilities in the use of the laptop and the need to test and experiment: "I thought that I would try to record in a few things myself and see how it works" (T9). This appeared to be an attempt to develop and expand the use of the laptop in new teaching methods. Another teacher noted encouragement by the school leader to use the laptops to help students in their learning process: "Use them [the laptops] as much as you can and use the in a way that supports learning" (T1).

Variations in laptop use in different subject areas were evident: "I have two subjects and in one subject, I use it a little more, that is Music. Here, I use the laptop every lesson. In English, I don't use it as often" (T2). One teacher reflected upon the connection between different subject area use as well as teacher use and student use:

"If they don't bring them we don't use them. Then I also think that it really depends on the subject, too. I know that the Swedish teacher for example, she goes crazy because the laptops are never there" (T5). Variation in different levels of classroom use by teachers was also seen to be a challenge. One teacher noted the use the laptop in combination with the interactive whiteboard with students: "There was a discussion about this this morning. The students want all of the teachers to do what I do. There are a lot of teachers who are not happy about this" (T1). There appeared to be variations in teachers' use of the laptops in classroom as well as variations regarding the level of use.

Laptops and Other Tools

Teachers expressed the use of the laptop as a tool, combined with other tools. One teacher used the laptop with the interactive whiteboard and an interactive Math book: "It works well in Maths. You can show it on the interactive whiteboard. I have my interactive book. There are examples… where you can click so that a graph changes and they can see which equations are related" (T1). The laptop also offered the possibility to find information and examples easily: "I have become dependent on it [the laptop]. As soon as I am going to plan some work, I look to find examples… it is fast" (T4).

The use of new tools in classroom work was also reported. For instance, one teacher used social media as an efficient channel to distribute information directly to students: "I have a Facebook account… Miss Sofia" (T1). One teacher also noted challenges related to the use of digital textbooks: "There are some digital textbooks, but they have not been connected" (T7). Another challenge in regard to student use, was according to the same teacher that: "Many students feel that digital textbooks are more difficult. It is hard to read them on the screen" (T7).

TPD

When the teachers were asked about TPD, they reported a basic course: "What is offered is the traditional basic course in interactive whiteboards" (T2). Another teacher reported new tools which were in the process of being introduced: "There is a lot going on with GoogleApps and this kind of thing… the cloud… and a new LMS (Learning Management System)" (T9). Another teacher expressed the introduction of new tools as a form of professional development: "There have been active whiteboards, GoogleApps, and things that happen all the time" (T10). Beyond these basic courses, other courses were offered, depending on available resources: "It is also up to oneself, if one can find courses. At the same time, there is a limited amount of money" (T7).

Beyond the individual TPD which was offered, teachers also reported collaborative efforts in teaching with the laptops. There were opportunities for teaching each other in collaborative learning in subject groups: "Our subject group is important.

So it is really up to us" (T3). Teachers also reported work in teacher teams and collaborative work to support each other's learning: "We also have teachers teach teachers and in our teacher team" (T3). Another teacher expressed this as sharing: "If there is something that we know, we show each other" (T4).

Teachers also reported further technical and pedagogical support in the form of workshops: "Every Thursday we can visit, well, we can go to a classroom and there is ICT training" (T10). One teacher noted challenges in having time and interest in increasing ICT skills: "I constantly feel bad… that I should be cleverer… But I think I do pretty well, but I don't have enough interest either" (T4). One teacher reported possibilities for the teachers and the schools to build competence through efforts in the work with the laptops: "The school is building up higher competence and higher use of smart technology where we can use the laptops more and use our active whiteboards" (T7).

Technical Problems

Teachers also brought up problems with mobile technology, and the connections related to teacher use and student use: "The technology doesn't always work. The students don't have the laptop with them" (T4). Another teacher discussed the technical problems related to a project:

> I have gotten good at finding solutions, so to say. All the terrible technical problems we had with the film thing [project]. And the cameras. The films were in the cameras, but we couldn't get the films over to the computers... And then we got an e-mail that the computers were going to be shut down. Everything has to be taken off the computers, Yes! We will take a few hours. We will book it in. We will do our best and see what happens. (T1)

Here, teachers took on a pragmatic stance of meeting these technical challenges when needed.

Teachers' Perspectives on Students' Laptop Use

When teachers expressed their perspectives on their own use, the following themes were seen: *student use*, *students' ICT skills*, *non-schoolwork use*, and *technical problems*.

Student Use

When teachers expressed their perspectives on student use, they reported several different types of use. This included digital and analog use. In certain cases, the teacher decided that the students had to have their laptops: "In the labs… they have to have them with them" (T6). However, this teacher also noted alternatives for students: “If they have a lab with a laptop, then they have them. But if they don’t… I say that it is better that they take notes by hand, you will learn better” (T6). Another teacher also reported challenges in student use in a project: “Many of them use their mobile phones to search for information, but when they presented, they were supposed to do a Power Point … and they said, I do not have my laptop. Well, why not?” (T3). There also appeared to be challenges related to when to use the laptop and when to draw by hand: “And then there are a few… I want to write on paper instead! Yes, well, ok. Do it. But this is tricky question, because, for example, I want them to draw in Chemistry and Biology, and this is difficult to do in Paint” (T1).

One teacher placed the responsibility for use on the students: “I have been a lot more like, ok, you take notes. Now you can use the laptops. Now you have to be responsible” (T9). Another teacher expressed that students have taken on this responsibility themselves: “I have seen that many [students] have put the laptop aside… they use it when they need it” (T6). Overall, teachers appeared to see a shift more in their laptop use than in student use: “I don’t think that there has been an increase… the students have their laptops and they are happy to use them. GoogleApps is still getting started for us… being able to add calendars and share documents which we haven’t done earlier” (T10). Laptop use remained at the same level: “Well for our computer programme… the number of students is increasing. Otherwise I don’t think that there is any difference in laptop use” (T7). Other teachers reported lower laptop use and more mobile phone use: “There are fewer and fewer laptops and more and more mobile phones” (T5). One teacher spoke about working on a blog assignment with students in class: “A few of them used the mobile phone. There is more and more of this. It is easier for them in some way” (T3).

Several teachers also reported changes in student use over time. This involved the strong interest in the first year to the final year: “I think they were new in grade 7… most of them do very well when they get to grade nine … they realize that, now, I have to work during lessons” (T1). This progression was noted by another teacher: “In their first year they are fascinated by the laptop. They can sit in the lessons doing something else. But in the second year… they realize, now I have to work… they should have realized this during their first year” (T6). The first year was reported as being the most “laptop-concentrated” (T5). Another teacher reflected upon this progression: “In part that they always had them with them, and in part that we used them. It has flattened out and I am not sure why this is the case, or if it is me, us or them” (T5).

Students’ ICT Skills

When teachers reflected upon students’ ICT skills in using the laptop, several teachers mentioned the need for a short introduction in ICT skills for students: “I think that it is too bad that they don’t have a short introduction in their first year in some way, a shorter course in the basics in Excel and Word" (T9). One teacher spoke of previous experiences of a short introduction: "…we put down a line for the laptops, they are to be used for this. Nothing else" (T3). Some of the teachers already provided this type of introduction: "We have a resource hour per week. The first week, we go through the laptop, the LMS, and all that. How to use Word" (T6). Over time, according to one teacher, students' ICT skills improved: "I thought that they would be more prepared and know more about Word documents… how to attach files … but they didn't. Now they do. They are also more critical about their sources." (T2). Another teacher noted that students see the laptop as a tool for spare time: "Some of them think more about the laptop being more of a spare time thing... and not so much that it is a school tool" (T2).

Non-schoolwork Use

Many of the teachers reported non-schoolwork use of the laptops:

> They use a great number of hours for games whether appropriate or not… we have glass walls in the classrooms and when you pass by many rooms, you can see that 95% are doing this. The teacher up front is doing something. This is not unusual. (T7)

Another teacher noted that these activities were not only related to laptop use: "they use the laptop for lots of other things than what they are supposed to be doing… but if they don't have the laptop they have their mobile phone" (T3). Teachers reported different solutions for dealing with this use. Sometimes speaking to students was enough: "Sometimes there is someone who is sitting and disrupting things, you can see that they are sitting and texting. But if you speak to them, they stop" (T6). Other teachers reported collecting mobiles at the start of the lesson: "…some programs have had a box in the front of the classroom" (T6). Another teacher summed up the use of laptops: "They have used them for writing and as a school tool, but I also think that they have been a source of frustration, a trap. But if they hadn't had their laptops, they would have had their mobile phones" (T9).

Technical Problems

According to the teachers, there were technical problems with the laptops as well as the need for technical support. Students complained that the laptops were heavy and did not work well: "They [Students] don't think they are good quality [laptops]" (T4). Another challenge was the lack of laptops to use if a laptop broke: "The technical support… if their laptop goes in [for repair], it is gone for a long time. There aren't any laptops to borrow. There should be many more. But of course, this is expensive" (T3). As expressed by one teacher: "I don't think that is acceptable for them to have to wait so long" (T4).

Field Notes on the Classroom Observations

Many of the reflections expressed by the teachers in the interviews were seen in the classroom observations. Teachers had their laptops with them for almost all of the lessons observed. Teachers used the laptops in their teaching combined with the interactive whiteboards for introducing and presenting materials. While almost all of the teachers had their laptops with them, many students did not. Overall, there were large variations in student use, which appeared to be related to the teacher's use, the subject area, the students' ideas of expected use during the lesson, as well as having a choice of using the laptop or not. The laptops and mobile phones were observed as a distraction in the classroom, but were also used as school tools.

Teachers' Perspectives on the Integration of ICT Over Time

Teachers at both schools were optimistic over time and reported a focus on laptop use as well their teaching activities with the laptops. The challenges reported were the time and need for TPD, technical problems and the need for pedagogical leadership for ICT. While the teachers saw possibilities in teaching activities with the laptops, there were technical problems. Teachers reflected both on the pedagogical use in their work in supporting students' learning, and in their own learning. The uptake and use of mobile technology in the classroom from Phase 1 to Phase 4 are illustrated in Table 5.1.

The instantiation of the ecology of resources model from the development of teachers' perspectives on their activities over time is illustrated in Fig. 5.2.

Discussion

In the resource element Environment, the need for teachers to support student laptop use manifests a filter. This filter most likely involves individual use and collaborative use for teachers. Thus, how teachers support the conditions for TEL and collaboration with the students in the classroom will most likely have an effect on student use. This is noted by teachers in this study who link own use to student use.

Teachers will most likely need to develop their own use in order to support students' individual use, but also to provide assignments which support students' collaborative use. Classroom assignments, tasks, and activities which are designed for use of the laptop in the classroom with the supervision of the teacher and which are aligned to, designed for and support TEL will also be important for the students' learning environment in the classroom (cf. Hauge, 2014; Jahnke, 2016; Olofsson et al., 2011, 2014; Perrotta & Evans, 2013). For teachers, TPD which involves pedagogy, technology and subject content would also perhaps provide a wider

Table 5.1 Teachers' perspectives from Phase 1 to Phase 4

Themes	Phase 1	Phase 2	Phase 3	Phase 4
Preparedness	Low, undecided level of preparation Optimistic or very optimistic view toward ICT	Insufficient preparation Optimistic view toward ICT	Optimistic view toward ICT	Optimistic view toward ICT and possibilities with ICT
Use	Low laptop use initially Increased use expected Technological awareness	Increased laptop use in school Shift from use toward reflective use Pedagogical awareness	Laptop use and technical problems Need for pedagogical leadership	Laptop use and technical problems Reflective, pedagogical use
Own teaching and learning	Opportunities for TPD expected Classroom management issues expected New forms of teaching expected	Time needed for TPD and teacher collaboration Classroom management issues for maintaining student focus Element of choice for students and teachers	ICT skills, access to planned TPD, time for TPD, time for collaboration Focus on student use and students' non-school activities Element of choice for students and teachers	ICT skills, participation in TPD, collaboration Focus on student use, students' ICT skills and non-school activities Element of choice for students and teachers

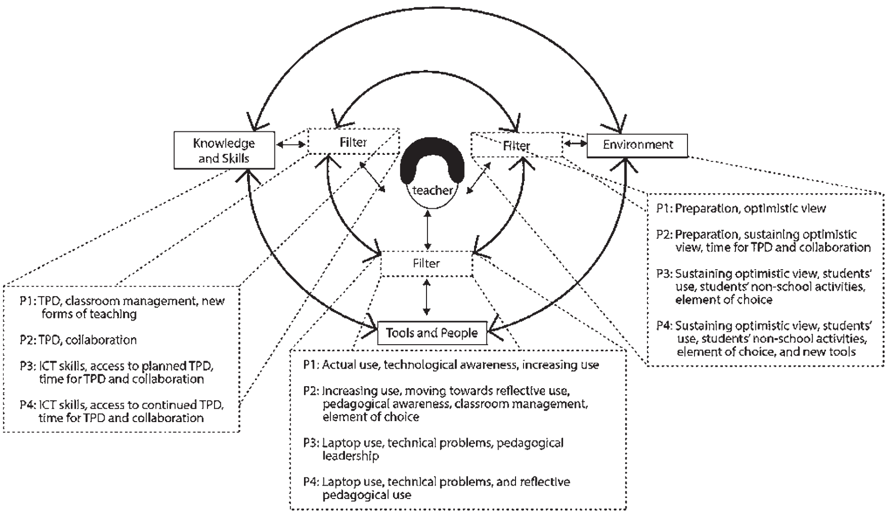

Fig. 5.2 Teacher perspective from Phase 1 to Phase 4. The ecology of resources model (Luckin, 2010). Elements and their filters

understanding for designing tasks and assignments specifically for the 1:1 classroom (Ertmer & Ottenbreit-Leftwich, 2010; Mishra & Koehler, 2006; Voogt, Knezek, et al., 2013). These skills may support teachers in their work (Drayton et al., 2010). It is most likely that in order to create conditions for TEL through individual and collaborative use, teachers will need to design and experiment with task design in the classroom. This could be said to manifest a filter in this resource element. However, this is something that the teachers in this study report, that is, the willingness to try new teaching methods in the classroom environment and experiment (Varier et al., 2017). Task design requires a move from traditional tasks toward new task designs for the digitalized classroom (cf. Jahnke et al., 2014; Olofsson & Lindberg, 2014; Selander, 2009). As noted previously, the teachers in this study were observed to have a wide range in variation in regard to integrating mobile technology and design for moving toward learning with technology in more meaningful ways (Jahnke et al., 2017). Teachers will need organized and systematic time to discuss the work in the 1:1 classroom together with their colleagues (Drayton et al., 2010; Vrasidas, 2015). In this study, how teachers support each other in their work and how school leaders support teachers' work for creating conditions for TEL in the classroom, as well as on the school level, will be of importance. If these conditions are not supported, it is likely that the building of competences in the school as a learning environment for teachers and students will be a challenge.

In the resource element Knowledge and Skills, TPD in ICT and subject-related skills for teachers are important (Hixon & Buckenmeyer, 2009; Tondeur et al., 2010; Vrasidas, 2015). In this study, the teachers reported that there is a need to develop their own ICT skills in order to increase the use of mobile technology. Here, these ICT skills can be linked to creating possibilities for TEL in the classroom with a reflective and wider understanding. Here, teachers need to implement mobile tools in order to make this possible (cf. Bocconi et al., 2013). In this study, teachers express the underlying possibilities in new ways of teaching through the use of interactive whiteboards and sharing documents in teacher teams. However, even when these tools have been implemented and are widely used, there will be the need for continued TPD (Tondeur et al., 2016). Thus, the lack of possibilities for TPD manifests a filter in this resource category. Further, the need for time to partake in these efforts can also be considered to manifest a filter in this category. According to the teachers, there are possibilities related to the use of the laptops to structure school materials, facilitate documentation, share materials and methods with colleagues. In the schools, teachers note that there are many tasks and different priorities and limited time (cf. National Agency for Education, 2013b). However, it is possible that ICT skills for teachers will facilitate the move from technology to pedagogy (Ertmer et al., 2012) and support student use of mobile technology in their learning. Moreover, teachers' ICT skills will also be of importance for supporting students' laptop use, through direct support for students, as noted in this study, when teachers discussed an introduction for students in their work with the laptops as a school tool.

Teachers' own uptake and use of mobile technology can be said to manifest filters in the resource element Tools and People. The same can be said for teachers' work in supporting students' uptake and use in school activities in the classroom. ICT skills for teachers and TPD will most likely support the uptake and use in the classroom (Dunleavy et al., 2007; Sipilä, 2014) as well as the time and opportunity to support experimenting with these tools. While some teachers see the potential benefit in using laptops and mobile phones as school tools in their teaching, others may need support in this process (Yeung et al., 2012). Thus, teachers may need help in sharing and collaborating within and across subject areas and finding time-efficient work methods (Ertmer & Ottenbreit-Leftwich, 2013; Towndrow & Wan, 2012). In this study, teachers note an increment in own use. However, from the teachers' perspectives it is difficult to see the same in student use. The teachers express possibilities in accessing information, examples, and pedagogical methods such as extra resources on the Internet. However, work will be needed to implement these skills directly in the classroom with the students.

It is possible that teachers are balancing when to use mobile technology in their teaching in assignments and tasks for students, and when to use traditional school methods (cf. Harper & Milman, 2016; Kopcha, 2012; Mishra & Koehler, 2006). Here, this pedagogical choice by the teacher is the result of pedagogical reflection regarding assignments and tasks and combining competences in pedagogy and technology. In this study, teachers report that the laptops were used in labs, but in some cases, the student was given the possibility to take notes and draw. In this choice lies responsibility. For teachers, this may mean expanding knowledge and using the laptop as a school tool in the classroom, as well as explaining and justifying this pedagogical choice for students. Thus, teachers' individual choice as well as students' choice of using the laptop as a school tool can be considered to manifest a filter in the resource element Tools and People. Challenges related to own and students' technical problems with the laptops as well as student use for non-school activities can also be considered to manifest a filter in this resource element. If technical support is offered, it will most likely be easier to achieve the possibilities for TEL in the 1:1 classroom. The same can be said of teachers' support in helping students to focus on classroom assignments. Helping students shift from non-school activities to classroom work will be important (cf. Andersson et al., 2014; National Agency for Education, 2013a, 2016).

This study identifies that the teachers are striving to combine pedagogy and technology to implement and design teaching with mobile technology as school tools in the classroom. Teachers report that laptops are considered as a resource in the 1:1 classroom. Teachers also report laptops being put aside in order for students to be able to concentrate on classroom work. Teachers also note that students must be asked to put away mobile phones, which they do if they are asked to. With the introduction of new tools, such as mobile phones, this also appears to be a way to manage this challenge. How teachers manage this challenge can be said to manifest a filter in the resource element Tools and People. According to teachers, laptop use appears to have decreased over time making way for mobile phones. The laptops as school tools appear to either be supplemented or exchanged in favor for mobile phones. Combining mobile phones and laptops as school tools may provide new conditions for TEL in the classroom, involving new and emergent practices for collaborative teaching and learning (cf. Cerratto Pargman et al., 2017). How teachers choose to take advantage of the possibilities, as well as taking on the challenges, in the use of mobile phones as new tools will be of importance for teaching and learning in the classroom (cf. Sung et al., 2016).

In returning to the research questions, the first research question posed was: *How can the uptake and use of mobile technology in the classroom in teaching activities be described and related to the conditions for TEL?* In the final phase of this study, Phase 4, teachers see possibilities in the use of mobile technology such as accessing information on the Internet and extra resources as well as new pedagogical methods. The findings also show that the possibilities from the teacher perspective are the use of the laptops to structure school materials, facilitate documentation, share materials and methods with colleagues in collaborative learning. Teachers see challenges in time for and access to TPD, technical problems, and supporting student use. One significant challenge is the lack of student use. The second research question posed was: *How can the possibilities and challenges in the development of the uptake and use of mobile technology in teaching activities over time be understood as conditions for TEL?* Using the ecology of resources model (Luckin, 2010), filters were identified in the resource elements. Teachers strive to combine pedagogy and technology to design teaching with the laptops as school tools in the classroom. While teachers appear to report an increment in own use, there are significant challenges concerning student use. The laptop as a disruptive force appears to have decreased over time making way for new mobile technology in the classroom, that is, the mobile phone. The laptops appear to either be supplemented or exchanged in favor for mobile phones in the 1:1 classroom. Teachers' efforts to support student use of both the laptops and mobile phones as school tools, taking advantage of the new possibilities for teaching and learning activities as well as the new conditions for TEL related to these tools are questions for future research. Both these possibilities and challenges can be related the conditions for technology enhanced learning and supporting collaborative learning and teaching processes with mobile technology.

Implications

This study points toward the need of supporting teachers in the ongoing work for integrating mobile technology of all forms in their teaching activities and designing for TEL. Based on this study, two recommendations can be provided. First, it will be important to take on the challenges in practice, such as supporting actual use for teachers and students in the classroom, including access and technical support. Second, stronger efforts in practice, such as access to and time for continued TPD, will be important to facilitate teachers' use and, in turn, student use. These efforts will most likely facilitate the uptake and use of mobile technology and facilitate the material conditions for collaborative learning and teaching processes. Combined, these recommendations may accelerate the uptake and use of mobile technology as school tools in the classroom and therefore support teachers' and students' work. Further, they will most likely support the conditions for TEL through transforming teaching and learning practices and exploring the relationship between the tools and technology as an emergent practice.

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Chapter 6
Is the Tablet a Teacher or a Student Tool? Emergent Practices in Tablet-Based Classrooms

Eva Mårell-Olsson, Peter Bergström, and Isa Jahnke

Abstract The aim of the study was to understand how digitalization of K–12 education has been carried out in Sweden. The focus lied on investigating 26 teacher's teaching designs in tablet-based one-to-one computing initiatives in Sweden. Further, the aim was to explore teachers' motives and practical implementation for teaching and learning in the one-to-one computing classroom. Data were collected through semi-structured interviews with 26 teachers along with 26 classroom observations in grades 2–12 (e.g., students from 8 to 18 years old). Activity theory was used for analyzing the participated teachers' motives, goals, actions, and operations involved in the integration of the tablets in the classroom. This study was part of a broader research project with classroom observations and student group interviews that was conducted during 2011–2015. The findings illuminate emergent practices based on teachers' strategies for constructing a teaching design that attempts to fulfill each student's individual needs. The findings also make clear that teachers are struggling for providing a customized education for all. In addition, the findings contribute to knowledge about how principals' strategic leadership (i.e., leadership and organization of the work in the school) has an impact on teachers' design practices.

Keywords Teachers · One-to-one tablet classrooms · Teaching · Learning · Students as consumers · Students as producers · Teacher tool · Student tool

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Introduction

Digitalization of education is a growing phenomenon worldwide. This phenomenon affects diverse types of stakeholders going from policy makers to individuals such as teachers and students. Sweden has shown an increasing digitalization of the school as almost all of its 290 municipalities have in some way implemented one-to-one computing initiatives (Becker & Taawo, 2017). Most of the research studies conducted in this context either focus on the innovative use of one-to-one computing and its potential for modernization and change of teaching and learning (Brown, 2006; Bocconi, Kampylis, & Punie, 2013) or on teachers' activities (Bergström, Mårell-Olsson, & Jahnke, 2019; Håkansson Lindqvist & Umeå universitet. Institutionen för pedagogik, 2015; Pegrum, Oakley, & Faulkner, 2013; Player-Koro & Tallvid, 2015; Saudelli & Ciampa, 2014), students' use (Håkansson Lindqvist, 2013; Norqvist, 2016; Tallvid, Lundin, Svensson, & Lindström, 2015), or a combination of both (e.g., Jahnke, Bergström, Mårell-Olsson, Häll, & Kumar, 2017). However, few studies have focused on investigating teachers' teaching designs based on their expressed motives for their teaching and how their motives are shaping and directing the practical implementation of their teaching designs in the one-to-one computing classroom. Grounded in a 3-year research project on the implementation and use of tablet-based one-to-one computing in Swedish schools (Vetenskapsrådet, 2013), this chapter contributes with critical insights into teachers' expressed motives behind their teaching designs and their practical designs-in-use for teaching and learning with tablets.

Background and Literature Review

In recent decades, the Swedish school system has undergone intensive reforms and restructuring that have led to fundamental organizational changes, such as the regulation of working hours, teachers' wages, and the use of work teams. This has a significant impact on working conditions for Swedish teachers (Lundström & Parding, 2011). The so-called *school choice reform* or *freedom of choice reform* was introduced in Sweden (Proposition, 1992/93:230; SOU, 1991/92:95) and allows parents to freely choose any school for their children. Schools receive an educational voucher for every student attending during the school year (Alexiadou et al., 2016). The deregulation of schools is part of an international trend (Lundström & Parding, 2011) and an effort to create a *school market* (Chubb, 2007). Since the introduction of these reforms, Swedish schools, like those in the USA, are competing for students, and the market logic affects working conditions in a way that Swedish teachers have never experienced before (Lundström & Parding, 2011).

Moreover, school statistics in Sweden are presented on a yearly basis by different agencies and associations as an attempt to measure school quality within a national comparison; for example, The Swedish National Agency for Education reports official school statistics, and the Swedish Association of Local Authorities and Regions presents statistics for years 6 and 9 and statistics related to individual subject grades for year 3 (see Municipality and County database, 2015). Since 2002, The Swedish Teachers' Federation has presented an annual ranking of the *Best School Municipality of the Year* with the purpose of inspiring municipalities to invest in those schools that create so-called *good schools*. Altogether, these reports can be interpreted as a sort of competitive ranking for whether a school provides a high-quality education, and Swedish schools can thus improve or worsen their positions in these rankings on a yearly basis. These results are also presented and discussed in the national and local media every year, with the media especially stressing which schools are ranked as "best" and "worst." A study about the effects of these annual rankings on the schools conducted by Hult, Lundström, and Edström (2016) showed that schools and particularly principals are pressured by the marketization of the Swedish school system while school funding is directly linked to success in attracting and retaining students. Another study concerning principals' strategic leadership in schools with established tablet-based one-to-one computing programs conducted by Mårell-Olsson and Bergström (2018) showed that principals consider the implementation of one-to-one computing to be a potential opportunity for organizational changes. Such an initiative acts as a tool for principals to implement practical changes and new teaching designs geared toward their own vision of what kinds of applied teaching designs and teaching methods should be used in schools. The principals' strategies on how to lead and organize the digitalized school have a strong focus on constructing a school that parents perceive as a "good" school (i.e., having a reputation for providing high-quality education to all pupils). The principals described that one-to-one computing in teaching makes it possible for teachers to adapt their teaching more easily and more efficiently to meet every student's specific needs for mastering all parts of the knowledge requirements in every subject. Thus, the principals' primary focus and endeavor is to improve their school position in the school rankings.

Since the time the school reform was put in practice in 1992, the digitalization of schools and one-to-one computing initiatives have increased tremendously—not only in Sweden but worldwide (Bocconi et al., 2013; Zucker & Light, 2009). A similar trend is seen in many countries regardless of the country's economic circumstances (Tallvid, 2015). For instance, the study by Mårell-Olsson and Bergström (2018) showed that school principals' motives and strategies on how to lead and organize the digitalized school try to meet the demands of *marketization* (e.g., to make the school more attractive and thus encourage parents to enroll their children in the school). However, this phenomenon of marketization has an effect on teaching conditions and sets new scenarios for teachers' designs for students' learning. For example, it can be questioned if the "attractive school" educates students in a meaningful manner or if education has turned to a "money model" where funding comes first and education second.

In general, the definition of one-to-one computing initiatives is based on teachers and students being equipped with a personal mobile device (e.g., tablet or laptop) connected to a wireless network along with software for educational use (Penuel, 2006). A recent study by Bergström et al. (2019) showed the role of cloud computing in sharing, storing, and retrieving information as an expanded dimension of the one-to-one computing environment (Gonzales-Martinez, Bote-Lorenzo, Gomez-

Sanches, & Cano-Parra, 2015). In addition, the digitalization of teaching, as Kress (2003) argues, makes it possible to use a multiplicity of modes (images, sounds, etc.), and it changes the representational and communicational actions of the users. Research has also shown positive effects of teaching designs with a purpose of constructing deep learning (Jahnke et al., 2017) and meaningful learning (Jonassen, Howland, Moore, & Marra, 2003) that include multi-perspectives on activities as learning by producing and creating new ideas (Jahnke, Haertel, & Wildt, 2015) and the use of alternative methods (Jahnke, Mårell-Olsson, & Mejtoft, 2016; Mårell-Olsson, Mejtoft, & Jahnke, 2015). Furthermore, research has shown that the use of tablets in teaching and learning fosters collaboration, creativity, and deeper knowledge among students (Jahnke, 2016; Jahnke, Norqvist, & Olsson, 2014).

However, school digitalization and especially implementation of large-scale one-to-one computing initiatives are not without problems (e.g., Håkansson Lindqvist & Umeå universitet. Institutionen för pedagogik, 2015; Tallvid, 2015). For example, 10–20% of the devices get broken in the first year, and teachers and parents complain about students' playing too much or being distracted by the devices. The parents also report physical problems such as neck pain or eye issues due to looking at the tablets for too long. Also, Zucker and Hug (2008) showed that teachers' practical use of technology in teaching varied by the subjects they were teaching. They found that English teachers used digital tools for writing assignments, while mathematics teachers tended to use digital tools for drill and practice and history teachers used the wired tablet mainly for asking students to do research on the Internet. However, because Zucker and Hug's study dates from 2008 and the tablets came into Swedish schools afterward in 2011, it is not known how teachers changed their classroom activities in recent years due to digitalization and rapid technology development. This raises two new research questions:

1. What do teachers try to achieve when integrating the tablet in the classroom and how do they implement their motives?
2. What kinds of actions do they take in the one-to-one computing classroom and what are the effects?

This chapter focuses on what teachers are trying to achieve when designing classroom activities in relation to their implemented teaching and learning designs in the classroom within the tablet-based one-to-one computing initiative. Further, we present results based on 26 classroom observations and 26 interviews in seven schools that have implemented tablet-based one-to-one computing initiatives in five municipalities in Sweden.

Theoretical Framework

To be able to understand teachers' reflected motives with their teaching and how this is directing their teaching and learning designs in the tablet-based one-to-one classrooms activity theory (Leontiev, 1986) was chosen as a theoretical framework.

The first generation of activity theory focused on the individual based on Lev Vygotsky's ideas about subject, object, and mediation (Engeström, 2001). Leontiev (1986) included not only the individual's actions, but also groups' actions within a social system. In Leontiev's version of activity theory, the individual is in focus, but the individual is understood in relation to the individual's actions, within a socio-technical system. In such a way, activity theory helps to make sense of a context in which the interplay between social relations, materials, tools, and motives directs actions in different situations, and it helps to understand the role of an artifact or a tool in everyday school life (Nardi, 1996). In our study, we viewed teaching designs as a form of materiality in the tablet-based classroom.

Furthermore, to be able to understand and describe diverse aspects of teachers' actions taken in the tablet-based one-to-one computing classroom, we investigated *how the teachers talk* about their teaching and classroom activities, and in turn observed what teaching designs they are implementing in the classroom. We selected Leontiev's concepts of *motives*, *goals*, *actions*, and *operations* for analyzing the empirical data gathered and for understanding better how actions are linked to each other. These concepts provided us with a terminology for the identification and analysis of teachers' expressed motives for their actions and the interplay among them. We focused on the issue of *what* is going on in the tablet classroom (i.e., *actions* and *operations*; the classroom practice) in relation to the question of *why* (i.e., the expressed *motives* and *goals*).

An activity, which is seen as a *system* according to Leontiev, includes the elements of motives, goals, actions, and operations. He argues that an individual person (e.g., the teacher) carries out *operations*, for example, routines or procedures, in relation to the conditions within a group or organization (the school). These routines or procedures are made of combined *actions* or work processes that are related to a *goal* that the individual tries to pursue. The goal is based on a *motive* that prompts and directs the individual's activity (see Fig. 6.1).

In this here presented study, the main focus of the data analysis has been on the participating teachers' expressed *motives* in terms of their expressed teaching *goals* and their expressed processes of realizing their goals (i.e., *actions*) and in turn how their expressed motives and goals are directing their practical teaching designs (i.e., *operations*) in the classroom. These processes within the educational system focus not only on the individual perspective (i.e., teacher vs. students) but also on the relations and interactions in-between.

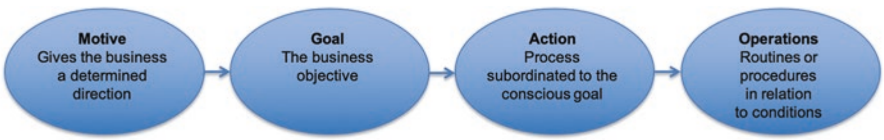

Fig. 6.1 Analysis criteria within an activity system

Study Context and Participants

Applying a purposeful sampling (Patton, 1990), seven K–12 schools in five municipalities were selected based on the precondition of having used tablets for more than 6 months within a tablet-based one-to-one computing program. In Sweden, these schools were among the earliest (Rogers, 2003) to start teaching specifically with tablets. In total, 26 classroom observations were conducted, and 17 female and 9 male teachers were interviewed. Five teachers worked in grades 1–3, eight teachers in grades 4–6, eight teachers in grades 7–9, and four teachers in grades 10–12. They had been working as teachers for around 3–39 years. Subjects such as mathematics, language and science, were taught during the observations in the classrooms. The class sizes ranged from 9 to 35 students.

Methodology and Methods

A qualitative approach was used to investigate the participating teachers' motives with their teaching (e.g., what they are trying to achieve) and their practical implementation of tablets in the classroom. We applied data collection methods such as classroom observation ($n = 26$) and semi-structured teacher interviews ($n = 26$). The focus of the interviews was on the teachers' stated motives and goals, as well as their experiences and described activities, linked to the teaching designs used in the tablet-based one-to-one computing classroom. The classroom observations focused on teachers' actual operations of the tablet-based teaching.

Data Collection and Analysis

The collected data were transcribed verbatim and coded into emerging categories based on the four activity theory nodes of *motives*, *goals*, *actions*, and *operations* (Leontiev, 1986) and then coded into emerging themes within each category using the software Nvivo. Nvivo has been used as a data analysis tool in a range of different projects (see for example Bergström et al., 2019; Dunleavy, Dextert, & Heinecket, 2007; Larkin, 2011). The interviews were used as a data set for analyzing the teachers' expressed motives and goals, and the classroom observations were used as a data set for analyzing the *actions taken* and the *operationalization* of the teaching designs in the classroom.

We used thematic analysis to construct an understanding and meaning of the empirical material. It led us to identify key themes and emerging patterns that we interpreted according to the activity theory framework (Ely, 1991; Leontiev, 1986). Boyatzis (1998) described thematic analysis as a process for encoding qualitative information. Further, he described how thematic analysis might be used to assist the researcher in the search for insight and how the process includes the two perspectives of "seeing" and "seeing as" (Boyatzis, 1998). According to Creswell (2013), *seeing* can be described as the process of searching for repetitive patterns of meaning (i.e., significance) in qualitative data, and the process includes several iterative readings for identifying the emerging patterns. The first step is the reduction of the data (coding), the second step is the presentation of the data (thematization), and the third step is the summation of the data in the form of conclusions and verification. In this study, the data were first coded into the emerging categories (i.e., motives, goals, actions, and operationalization) and then into emerging themes within each category. For example, themes concerning what the teachers described in relation to what they wanted to achieve with their teaching were categorized as *motives* and *goals*. Themes concerning how they organize and implement their teaching designs in the classroom were categorized as *actions* and *operationalization*. A *theme* is described by Ely (1991) as a definition of a single statement of an opinion that has a great emotional or actual significance or utterances that all informants in a study are expressing. The phase of constructing meaning, or "seeing as," involved searching for signs and patterns at a more abstract level in the teachers' utterances. For example, regarding what they explicitly or implicitly were saying in the interviews, as a step toward making sense of the coded material. These iterative processes formed the emerging themes in the material as presented in the next section of results.

Quotations presented in the "Results" section illustrate the emerging themes from the analysis of the empirical material (i.e., the interviews and classroom observations).

Results

The results illuminate teachers' teaching designs in the tablet-based one-to-one computing classroom. The results are presented in four themes:

1. Preconditions for designing teaching and learning with technology
2. Focusing on adapting assignments to each student's specific needs
3. Activating self-motivated students
4. Perceiving the tablets as the teacher's or the students' tool

The first theme concerns the preconditions that the teachers have to deal with when designing for teaching and learning in one-to-one computing classrooms. The second theme concerns the participating teachers' endeavors and their expressed motives with what they want to achieve with their teaching design. The third theme concerns their expressed focus and what they are aiming for with their teaching design (i.e., goals and actions). The fourth theme concerns teachers' practical implementation of their teaching designs in the classroom (i.e., operations).

Preconditions for Designing Teaching and Learning with Technology

In our previous study (Mårell-Olsson & Bergström, 2018) regarding principals' strategic leadership concerning how they lead and organize the one-to-one computing initiative in Sweden showed that the marketization of schools and the national tradition of presenting annual rankings of schools' results have a great impact on schools' financial situations because they receive a voucher for every attending student. These external evaluations and the competition for attracting students to schools affect how the principals organize and manage their schools when implementing the tablet-based one-to-one computing initiative. This affects the preconditions they provide for their teachers. How principals lead and organize tablet classrooms at their schools influences the applied teaching designs in the one-to-one computing classroom. During the interviews with the teachers in this presented study, they expressed how the principals at their schools were providing the preconditions for their own working conditions with one-to-one computing. For instance, one of the teachers (ID31) explained to us that the principal started the tablet implementation process by asking "How do we get better [student] results and better ranking for our school?" As indicated in the quotation, the digitalization of this school was seen as an attempt to improve the school's results.

The preconditions that affect teachers' teaching designs with tablets are based on the principals' endeavor and strategies to construct what parents perceive as *a good school*. For example, this might mean a school with a reputation of providing high-quality education to all students and that maintains high positions in the yearly rankings. From a principal's viewpoint, it is relevant to have enough students enrolled in the school (at least 28 students per class according to our interviews) that results in a balanced budget and gives the principals sufficient resources to allocate resources where they are needed the most, for example, supporting low-performing students to help them to successfully pass their courses (Mårell-Olsson & Bergström, 2018).

As such it became clear that the principals were setting the scene for the tablet implementation and laying the foundation for the teachers' work (Mårell-Olsson & Bergström, 2018). In teacher ID31's school, they focused on formative assessment methods and self-regulated learning in combination with the use of tablets in teaching. The tablets were used for communication purposes foremost and for increasing the students' motivation for doing schoolwork. In turn, the teachers believed that this would result in increased school performance. The teacher explained:

> *We wanted to find a greater opportunity for creativity and flexibility in teaching and also real opportunities to work within the time constraints and other frameworks that we have with formative assessment in a sensible way. Thus we needed digital tools to communicate digitally with students. Otherwise we will never get to that. That's the main idea really (Teacher ID31).*

Table 6.1 Cluster of preconditions

Cluster	Description of preconditions/principals' visions	Teachers
1	Focus on the low-performing students	ID04, ID13, ID17, ID19, ID23, ID27
2	Self-regulated learning	ID08, ID12, ID17, ID20, ID27, ID31
3	Improving school results	ID04, ID06, ID15, ID31
4	Making teaching and learning more "fun" for the students	ID01, ID03, ID19, ID21
5	Focus on improving formative assessment	ID30, ID31
6	No specific preconditions set by principal or not expressed clearly by the teacher	ID02, ID05, ID07, ID12, ID14, ID16, ID18

Table 6.1 presents six clusters of preconditions that we identified for all 26 teachers.

In summary, Table 6.1, informs that a focus on low-performing students and improving the school's results were the preconditions in ten schools, self-regulated learning and improving formative assessment were seen in eight schools, and in seven schools the principals had not set a clear vision for tablet use in the classrooms.

Focusing on Adapting Assignments to Each Student's Specific Needs

From the analysis, we found that the teachers saw an opportunity to adapt their teaching designs to each student's specific needs with the tablets than without them. More in particular, we found that teachers were trying to achieve a teaching/learning design that would enable them to ensure that all students are able to participate in the classroom activities. According to the teachers interviewed, it is of great importance that none will be left out. There was a strong focus by the teachers on trying to ensure that every student meets the knowledge requirements and passes every subject every year. Teachers reported the use of tablets as contributing to this need to a great extent. The teachers argued that it is easier to adapt the teaching designs with tablets to all students in the classroom, regardless of whether the students are doing very well or if they need extra help or attention. The teachers described the tablet as a flexible tool that enabled them to adapt their assignments and adjust their teaching design to every student's specific level without too much effort. The teachers also reported that they were able to redesign their plans in the classroom "on the go" if necessary with the support of the technology. Earlier, in situations without digital devices, it was perceived as very time consuming to do this, as one teacher reflected by pointing at the tablet: "Now I don't have to print everything. Everything is right here" (Teacher, ID19, teaching history in grade 11).

Another teacher clarified:

> *Now when some of them are watching movies I can go from child to child talking with them. This way I can reach the children who need extra support with writing, and I have time to help them with this. It is a very good way to catch up with everyone else, too (Teacher, ID12, teaching religion in grade 3).*

In summary, the teachers used the tablets for changing their teaching designs in a way that would support every student's specific needs toward mastering all parts of the knowledge requirements in every subject. This ensures continuous student achievement and improvement by giving them a customized education. This can be seen as the teachers' endeavor to achieve what can be described as *educational participation* for all students.

Activating Self-Motivated Students

Variation (e.g., action; Leontiev, 1986) is a method used by the teachers to maintain the student's own drive (i.e., inner motivation) to complete their schoolwork and to help them remain as active, self-motivated agents throughout the entire lesson. In the classroom observations, we found that the teachers' teaching designs to support student learning established variation on different levels such as: focusing on different topics, alternating assignments during the lesson time, changing working methods between individual work and group work, oral discussions, writing tasks. As mentioned in the previous theme, the participating teachers perceived the tablets as a flexible tool with numerous in-built functionalities that helped them to fulfill these demands for varying the activities during the lessons. A key factor for creating active and self-motivated agents in the classroom was to motivate students to do the schoolwork. This requires a design that keeps them motivated and active during the whole lesson. One teacher explained:

> *It's important that they [students] take responsibility, and it is important that they show and yes… it is important that they really want to learn. It is important for me to try to motivate them to want to learn. I try to make it more fun, a bit smoother, a little more accessible and a little more flexible so they will stay active (Teacher, ID05, teaching math in grade 12).*

Another teacher mentioned:

> *I try all the time … to think that I should vary the work. I had to activate them [the students] at a very early stage and change things up frequently. It automatically leads to a variety, of course, when one tries to switch tasks, change the tools, change seats, and so on. This is necessary to keep them constantly alert (Teacher, ID01, teaching math in grade 3).*

The tablets were described as a useful tool for creating variation in the classroom as the teachers found different software applications (apps) that could be used in different subjects and for different purposes. The teachers' action of *variation* also included the possibility to adapt assignments and working methods to students' individual needs, especially regarding those students with difficulties in reading and writing. One example of variation applied with the specific purpose of motivating students to do schoolwork is when teachers allow them to use edutainment apps for practicing the multiplication table or similar repetitive tasks. These types of apps created for educational purposes quite often have in-built games with different levels of difficulty and are often presented with a gamification style. A student can then choose where to start and where to continue, trying to achieve the next level or step with a higher difficulty, known as "leveling up." The observations showed that these edutainment apps—games with an educational purpose—were specifically used at the ends of the lessons. Often, they were used as reward or when the students had finished all of the other planned activities. This way of letting the students play edutainment games was one way of keeping them active as self-motivated agents throughout the whole lesson. It was obvious that the students really liked these types of rewards and were playing with great intensity and joy. They often asked the teachers several times at the beginning of the lesson, especially the younger students, *if* and in that case *when* the time for playing a certain game would come.

The applied teaching designs, in which teachers are trying to adapt the assignments to each student's individual needs, were focused on activating students as *self-motivated agents*. Using *variation* as part of the teaching design also serves the purpose of freeing up teacher time during class to be able to focus on the low-performing students and to help them to complete the assignments.

Perceiving the Tablets as the Teacher's or the Students' Tool

The teachers operationalized the use of tablets in their classrooms differently. They could be divided into two groups. One group of teachers perceived and used the tablets as *the teacher's tool*, while the other group of teachers perceived and used the tablet as *the students' tool* (Fig. 6.2). Perceiving, designing, and using the tablet as a teacher tool or as a student tool has implications for the implemented teaching designs and, in turn, how the tablets are actually being used in the classroom.

The group of teachers that used the tablet as *the teacher's tool* varied their collected digital resources, and they created digital teaching material that they distributed to their students. According to the teachers who belonged to this group, they tried to avoid students becoming bored, and they motivated them to continue doing their schoolwork by distributing different digital resources. The teachers collected articles and interesting websites, they created written instructions on their subject and assignments, and they recorded instructions and published them on their own YouTube channel, for example, and distributed them to their students via cloud services. Teachers collected and used different sources from the Internet to a greater extent than they used traditional teaching materials such as textbooks. One teacher described how she used YouTube for distributing videos and instructions to students:

> *I'm using YouTube a lot. Both self-produced and other YouTube clips I borrow from other teachers. For example, a TED talk that we used yesterday. It has native English-speaking persons the students can listen to. I have also recorded my oral instructions in front of the*

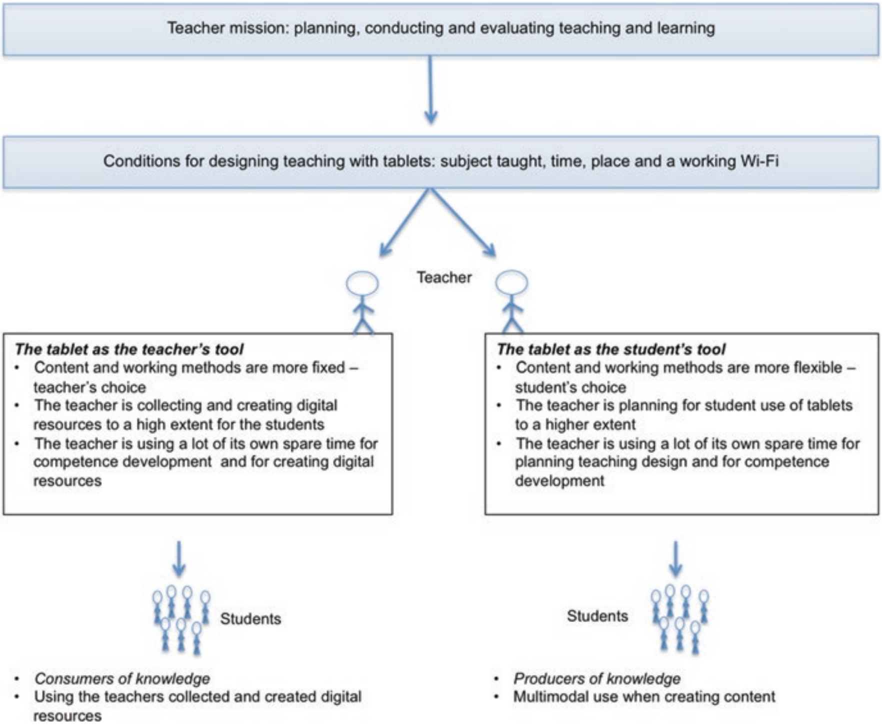

Fig. 6.2 One group of teachers perceived and used the tablets as *the teacher's tool*, while the other group of teachers perceived and used the tablet as *the students' tool*. Differences were seen in how they designed their teaching with tablets: teacher's choice of content, working methods, collections of resources

> *whiteboard so that they [the students] can watch it repeatedly. I'm just recording on the tablet during the lesson time while giving the class instructions. I found that the best way is to just put it up and push record. Then I don't need to edit anything. Usually I'm also e-mailing them websites I want them to look at (Teacher, ID06, teaching languages in grade 10).*

Another teacher said:

> *I can often spend two and a half hours on a Sunday searching for useful apps to use. Often, I'm downloading 5, 6, 7, 8 and looking them through. Is this app useful or not? For each successful or useful app, I have rated at least 9, so 1 out 10 I can use. It takes a lot of time, but my own kids can use them so it isn't a waste of time. It's fun and I can also use an app several times. I don't have to throw it away (Teacher, ID08, teaching math in grade 8).*

The teachers who perceived and used the tablets as *the teacher's tool* had as their main activity distributing information via the tablet to students, and in turn the students became the receivers of information. Thus, the students could be seen in this situation as *consumers of knowledge*.

The other group of teachers perceived, designed, and used the tablets as *the students' tool*. They positioned the students as creative producers and supported them in this role. These teachers varied their teaching methods and designed active assignments to focus instead on the student's *production of knowledge*. According to the interviews and the observations, this group of teachers designed their teaching *for* students to take on a new role as active producers where the students produce their own movie clips or use images in combination with texts and produce their own books. The students belonging to this group of teachers were approached as the *producers of knowledge*.

One teacher explained during the interview:

> *Last year I started to think about whether I could do it [teaching] in another way. I saw someone on Facebook who had let the students produce their own instructional movie-clips. It was in another subject, but I thought that I also could do it. If I could get them [the students] to be more motivated to produce films than writing on paper, it would also end up that they would practice more on the topic. They thought it was fun. When we had finished the production of the movies, I let them sit in groups for the test. This way they discussed the topic more. All of them were sitting there with their own specific knowledge and sharing it with each other. Well, I thought it worked very well (Teacher, ID07, teaching languages in grade 7).*

The teachers in this group often described themselves during the interviews as not very competent from a technological perspective when using the tablets. However, they stated clearly that it does not matter because the students have the skills to use the devices and they can help each other as well as help the teacher if needed.

One teacher said:

> *They [the students] are so technical. I don't care so much to learn myself, but they are so interested and they find new things all the time. There are so many possibilities, and I mean they have the time to sit and play. Sometimes they do amazing things. I learn from them. There is always someone in the classroom who knows how to solve things (Teacher, ID03, teaching social sciences in grade 6).*

Both groups of teachers were designing their teaching using variation as an *action* to motivate, engage, and activate students to learn. Their endeavor (e.g., motive) and goals were focusing on students as self-motivated agents, but they were carrying out their teaching designs differently. The first group of teachers applied a design directed at teaching (i.e., a *teaching design*), while the other group of teachers applied a digital didactical design (Jahnke, 2016) for promoting learning (i.e., *a learning design*).

Discussion and Conclusions

The preconditions for the teachers in this study are the marketization reforms of Swedish schools (i.e., the school as a market) and the principals' efforts to foster *a good school* of high quality (e.g., having a balanced budget, see Mårell-Olsson & Bergström, 2018). In line with the principals' endeavor of improving the school's position in the rankings by getting better student results, the teachers put efforts into teaching designs with a strong focus on helping students who are at risk of not reaching the knowledge requirements, while the other students in the classroom are working by themselves as self-motivated agents. Such an emergent school practice raises new questions. How will this strong focus and attempts to ensure that all students receive passing grades by any means affect overall Swedish student knowledge and learning acquisition? The implications from the emergent practices of the seven schools in this study are that teachers need to prioritize and support those students who need their help the most. In turn, additional consequences are that teachers do not have enough time and resources to spend on those students who want to go further and who need more challenging tasks. There could therefore be a risk—when students to a great extent work independently or in groups without a teacher there to ask challenging questions on content and to guide them through solving problems—that the schoolwork might be perceived as boring and not challenging enough. Even an active, self-motivated student needs to be challenged in some way to maintain the inner drive to continue and complete assignments. The individual teacher's efforts in varying their teaching design and using the tablets as teachers' tools or students' tools could therefore be critical for supporting deep (cf. Jahnke et al., 2017) and meaningful learning (cf. Jonassen et al., 2003).

Consequently, multilevel strategies are needed. The use of technology must be able to support and adapt to the educational expectations and the schools' requirements, as well as to different teaching and learning methods (Jahnke, 2016; Jahnke et al., 2016; Mårell-Olsson et al., 2015). Such strategies can include, for instance, *apps* that help teachers personalize students' learning (e.g., Google Classroom, Apple Classroom, Go Formative). In addition, adaptations to various pedagogical requirements might be useful, for example, increased efforts, time, and resources along with adequate competence development for teachers that addresses both pedagogical methods and different uses of technology for increasing digital competence. This is especially true regarding the construction of real opportunities to challenge each student to reach as far as they can regardless of their knowledge level. A solution could be toward a digital didactical design (Jahnke, 2016) that promotes the use of tablets as *the students' tool* (cf. Kress, 2003) in which the students are allowed to be the "drivers" and "navigators" (Mårell-Olsson, 2012) of their own educational journey. A shift is probably also needed toward a learning design in technology-rich environments that supports and encourages all students to learn as much as they can by making use of alternative methods (e.g., game-based learning), but without sacrificing proficiency. This might stimulate student desire for knowledge acquisition to a greater extent (see Jahnke et al., 2016; Mårell-Olsson et al., 2015). A shift in teaching designs toward meaningful technology-based learning (Jonassen et al., 2003) might also be useful in reversing the trend of low school performance in Sweden and other countries in recent years (PISA, TIMSS, etc.).

Limitations

A methodological concern about this study is the selection of informants. We assume that we could have obtained more extensive data and richer nuances if we had included more schools, conducted more observations and interviews with teachers, and even included the students' narratives and perspective in this context. However, the collected material overall was quite extensive, and due to time limits it was not possible to include more schools and more informants. In this case, it is hard to know if we could have drawn different conclusions with even more extensive material.

Another methodological issue concerns the analysis of the empirical material using the concepts of activity theory. The main critique of this theory is that individuals do not need goals to pursue an activity; instead, they might take an action without a specific goal in mind but when asked afterward they might try to construct a goal. However, the aim of this study was to investigate the actual actions taken by teachers and their stated motives when designing classroom activities in this context, and the theory helped to shed light on teachers' teaching designs with tablets being used as a teacher's tool or a student's tool in the one-to-one computing classroom.

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Chapter 7
WhatsApp with Science? Emergent CrossActionSpaces for Communication and Collaboration Practices in an Urban Science Classroom

Jennifer D. Adams

Abstract This chapter describes an emergent practice of using the digital application WhatsApp to transcend the temporal and physical space of an urban science classroom forming a CrossActionSpace. The group communication application afforded the extension of a teacher's vision of mutual trust and collective success into a sociomaterial space of communication and collaboration. I introduce the notion of critical agentic bricoleur to describe how the teacher used this existing digital resource in new ways and resonant with his teaching identity. I analyzed the discourse generated in WhatsApp to make sense of the unfolding social practices of science learning. I discuss how the agency developed in this CrossActionSpace is transcendant and creates the conditions for all participants to develop identities that are resonant with imaginations and realizations of academic advancement.

An Emergent Space for Science Learning

Classroom teachers are often challenged with the use of everyday digital technology in the classroom. For some teachers, smartphones present a distraction with some teachers or schools even banning smartphone use during instructional time. However, as our cultures become more digitally embedded where our interactions are both physical and digital at once it becomes increasingly difficult to separate these two (or more) modes of communication in formal learning environments. As Jahnke's notion of CrossActionSpaces (Jahnke, 2015) describes, there is a merging of offline and online worlds in ways that expand and intersect both classroom and out-of-classroom boundaries. For science teachers in urban schools this potentially creates expanded opportunities for science teaching and learning that

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affords students access to voluntary out-of-classroom resources to support both their interests in science and encourages their success in institutional measures of science achievement. Furthermore, as learners choose whether and how to engage in these spaces, it expands their agency in learning, something that often not attributed to racialized urban science learners.

In this chapter, I describe an emergent practice in an urban science teacher's classroom, with the notion of classroom transcending the temporal and physical space that defines school. Specifically, I discuss how the smartphone in conjunction with a group communication application afforded the extension of a teacher's vision of mutual trust and collective success into a sociomaterial space of communication and collaboration beyond his classroom.

I employ the hermeneutic approach (Tobin & Ritchie, 2012) where I analyze the discourse generated in the social media space as text to make sense of the unfolding social practices in an urban science classroom as it transcends the physical space. Through this writing praxis, I use my theoretical lens of teacher identity and experiential lens from my own practices of science teaching and learning, to describe and make sense of this teacher's evolving practice and corresponding identity formation vis-à-vis the emergence of this sociomaterial space as both reflection of his identity as a science teacher, his vision of classroom culture and science learning and the salience of this for equitable and meaningful science teaching and learning. Furthermore, my stance as a critical researcher compels me to reflect on how this teacher's practice produces spaces of success in science for his Black and Latinx students who are often left on the margins in terms of access to rich and meaningful science learning experiences (i.e., Adams & Gupta, 2013).

The Collaborative: A Collective Space for Learning About Teacher Identities and Learning to Teach

I have known Mr. V for almost a decade, first as a teacher education student, then a near-peer mentor on a grant project and now as a research participant/teacher mentee in my research group. I led the research group, entitled Collaborative Teacher Inquiry around Informal Science Learning and Science Teaching in Urban Classrooms (hereafter the Collaborative) that was structured around a National Science Foundation project (of which I was the Principal Investigator), Informal Learning Environments and Teacher Education for STEM (ILETES) to learn about the relationship between learning to teach and teacher identities. Specifically, this project examined how informal science teacher learning experiences influence new teachers' identities and teaching enactments. Teachers invited to participate in the Collaborative were within their first 5 years of teaching as it was important to learn about their developing identities. Furthermore, they all took teacher-certification courses during their undergraduate education that focused on informal science education, with the goal of incorporating informal science resources (museums, zoos, parks, etc.) and approaches in their teaching.

The Collaborative included seven STEM teachers and met on a bimonthly basis for 3 years where they shared and discussed their developing practices of teaching science. The primary means of data collection during these meetings was through cogenerative dialogues (hereafter cogens), structured discourses designed to identify issues in teaching and learning and to generate new meanings, understandings and solutions or actions around shared experiences (Martin & Scantlebury, 2009). During these meetings the participating teachers shared their reflections of adapting informal science learning practices into their classrooms along with corresponding successes and challenges. They also shared artifacts of their teaching that ranged from lesson plans to student work to digital artifacts (photos, videos of their classroom, etc.). Discussions often extended to include the sociocultural factors of teaching in a large, diverse urban district, which is inseparable from the acts of science teaching. Additionally, most of the teachers in the Collaborative identify as Afro-Caribbean, African American, or Latinx, and this often showed up in discussions about being a teacher of color in relation to teaching students of color. In the Collaborative, I had the role of both researcher and professor as most of the participants took credit-bearing courses with me during their preservice teacher education. Moreover, I also taught high school science in the same urban district and then in a museum, where participants in the Collaborative also took courses and professional development. Therefore, as an Afro-Caribbean woman I was able to engage in what Rita Kohli (2014) terms "reciprocal vulnerability" where as an act of mutual trust, I shared my experiences of science teaching in formal and informal settings as well as my own notions about and experiences with equity, especially for Afro-Diasporic and Latinx students in STEM in urban schools.

Through participation in the Collaborative, the teachers developed collective understandings of informal science learning in relation to the formal classroom, and imagined, enacted and adapted informal science learning in their classrooms in order to both resonate with their identities as teachers and their visions of student success in their science classrooms. The data I collected included video and audio recordings of the cogens, teaching artifacts, such as lesson plans, photographs and student work that the teachers brought into the cogens, social media interactions with teachers and field notes of field trips that I facilitated with the participating teachers. Mr. V emerged as a reflection for this chapter because of his novel use space in his teaching, both the physical space in the classroom and in the virtual space where the classroom, science learning and youth-centered ways of being and interacting all intersect. Mr. V consented for me to write about these interactions for this chapter. Here I will describe the ephemeral yet impactful digital space he and his students co-created for students' success on a compulsory standardized exam. Using the following questions I reflect on the "innovative" and "unexpected" application of social media in a high school Earth science classroom:

1. In what ways did the use of a social media application resonate with the teacher's identity and vision of science teaching and learning?
2. What were the affordances of a social media application that contributed to mutual trust, collaboration and student success?

3. In what ways did both student and teacher roles and agency emerge and change in the use of the application?

With sociomateriality conveying "an understanding of learning that is situated and embedded within an activity, context and culture and bounded to artifacts making such activity possible" (Cerratto Pargman, Knutsson, & Karlström, 2015), this chapter will describe and reflect on the use of the social media platform WhatsApp as situated within the broader context of Mr. V's unique classroom pedagogy that centers youth ways of being in the world, mutual trust, and self-directed learning, all towards the goal of students' individual and collective success on a compulsory standardized exam.

Identity and Agency

Teaching and learning are, in essence, two sides of the same coin. A teacher is always a learner in that he is not only deepening his knowledge of subject matter but also learning about himself, as a teacher, as he interacts with his students in different learning spaces. This also includes the constant re/creation of learning spaces in order to adapt to his goals as a teacher and the identities of his students as diverse learners. Nasir, Snyder, Shah, and Ross (2013) describe learning, identity, and goals as relational and evolving together in social practice. The outcome of this is agency, where the learning is defined by how learners access and appropriate resources at hand to meet learning (and teaching) goals. Agency in teaching is the "belief that the self is capable of making the right instructional decisions, knows how to acquire and use resources to teach, and confidence about constructing and maintaining a safe and effective learning environment" (Adams & Gupta, 2017). However, agency is not a fixed end-point but rather a constantly evolving entity as a teacher/learner engages in different social practices and spaces. For science teachers, materials are central to creating effective learning environments; having access to laboratory spaces, equipment, physical specimens, and other visual and tactile objects is critical to teaching and learning in the STEM disciplines.

However for science teachers teaching in spaces that are resource-challenged, agency also means becoming, what I am calling, a *Critical Agentic Bricoleur*, the ongoing augmenting and adapting resources at hand into new science teaching and learning engagements with special attention to attenuating the challenges faced by students marginalized from science. This newness also includes the incorporating of cultures, such as youths' language and ways of being in social spaces, which are usually relegated to outside of the classroom, into teaching and learning towards student engagement and success. This notion of being a Critical Agentic Bricoleur speaks to the sociomaterial entanglements that constitute STEM teaching and learning—the intersections of physical and digital resources and spaces, bodies, languages and cultures in the conceptual science classroom. In the following sections I illustrate how Mr. V, as a Critical Agentic Bricoleur, used WhatsApp, a digital app that youth use as a means of communication in their daily lives, as a resource for collaborative science learning; specifically how he used this platform to confirm group solidarity around success on a high-stakes exam. In this CrossActionSpace that constitutes his physical classroom and the digital space of WhatsApp, Mr. V created and recreated the collaborative, student-centered, multimodal learning environment that characterizes his approach to teaching. Also central to Mr. V's pedagogy is building a strong culture of trust in his classroom. He has a strong belief that if students feel safe and acknowledged then they will be more open to taking learning risks in the classroom. This risk-taking leads to more positive and successful interactions with science learning. Furthermore, with trust being foundational to his way of being in the classroom, I show how the emergent practice of WhatsApp, as a science teaching and learning resource contributed to the extension of a positive learning culture of mutual trust, collaboration and academic success in this CrossActionSpace.

Awe and Wonder in the Science Classroom

Mr. V is an Earth science teacher in an urban high school. This school is located in a lower socioeconomic community, and, as is often the case with such schools, the predominant demographics are historically racialized and minoritized students who have experienced years of subpar schooling and have, as a result, largely disengaged. This is evident in the state test results where Mr. V reported that there has been consistently low passing rates; in the year prior to Mr. V' appointment it was less than 10%. These tests are required for graduation so students either repeat the class until they pass or get pushed out of school. Being a graduate of the city's public school system and a minoritized person himself, Mr. V empathizes with his students and maintained his commitment to teach in the City despite administrative pressures. In one Collective meeting he described the reduced pressures he would have teaching in the suburbs, including not having to worry about low passing rates,

> But then as I was reflecting on it, that's not why I became a teacher. That's the easy route, you know if I do that, I'm going to become a sell-out. No. I need the challenge. I need to help the individuals that remind me of my friends and my situation growing up. So, I stuck to the school and I think I'm going to just ride it out for a few more years and, just stay there.

However, more than ride it out, Mr. V actively imagines and creates novel ways to keep his students engaged in science learning, including the use of communication technology as a means of sustaining the social bonds, both to each other and to the subject that developed in the classroom. Mr. V has a natural way of integrating students' ways of being and communicating in his teaching and this creates spaces for success in science for students for whom this success is often elusive. To an outside observer Mr. V's classroom may seem noisy and even a little chaotic. As an urban denizen myself, Mr. V's classroom reminds me of the controlled chaos of the city's streets where people appear to be random and engaged in diverse activities but there is a collective direction—everyone has a place to go and a path to get there.

However a careful look would reveal a careful structure where students are engaged in science learning but allowed to be "teenagers"—highly vocal, physically active, and exchanging jokes with each other and Mr. V. In later sections of this chapter, I will share some vignettes to illustrate Mr. V's teaching and learning culture.

During the Collaborative meetings, Mr. V often lamented about the numbers and how his success as a teacher was judged by passing rates, no matter how innovative his teaching and engaged his students. As a new teacher, Mr. V saw this constraint as an opportunity for expansive teaching, learning and agency in his classroom. Because the Collaborative was structured around informal science learning, Mr. V queried in an early group meeting,

> Why can't we just put the informal inside the classroom, why does it have to be outside the classroom? When you think of what it is; we are learning, we're relaxed, we're critically thinking, why can't we just do that in the classroom?

Like other members of the Collaborative, Mr. V's teacher education at the public liberal arts college, included informal science learning through courses that were done in collaboration with a natural history museum and through various summer activities that were structured through the preservice teacher education program. He and others in the group reflected on these as being meaningful learning experiences for them as teachers and strived to recreate similar learning experiences with their students. However, most of emphasized reproducing fieldtrip-type experiences. Mr. V challenged the group to recreate meanings of informal science learning for the formal, urban science classroom. Mr. V wanted to have "awe and wonder" *in* his classroom too, not just on field trips.

Being an "Informal" Teacher

Mr. V identifies himself as an "informal science" teacher; he mentions this whenever he describes his pedagogy or simply stating the kind of teacher he is. This stands in contradiction to his emphasis on the standards and assessments that both judge him as a teacher and his students as learners. In the urban district where he works, the teachers are subjected to stringent rating systems based on the Danielson Framework (Danielson, 2011). Although Danielson herself has denounced this subjectification of teachers (Danielson, 2016), this framework persists, and some teachers view it as a mechanism to undermine their sense of agency in the classroom. Mr. V, for one has always mentioned this Framework both as a goal and a constraint to his teaching. During a goal-setting meeting at the beginning of a term he mentioned having a "highly effective" rating as his goal, along with successful classroom management and good relationships with his students. For him, maintaining a student-centered environment is key to achieving these goals,

> You know…I have a vision of what they should be doing, what I want them to do, but to present it in a way where it's informal. It's creating that environment where they can drive and succeed but at the same time they're choosing their path to get the result that…I present in the beginning.

He related this to norms of visiting informal science institutions,

> When you first asked us how we talk about informal [science], it's a museum and an exhibit and a zoo. You know what is the first thing they had you, they hand you a tri-fold paper with the lists of all the exhibits, a map. And you are free to wander and learn in that environment and go anywhere. And they have a plan. The plan is [that the visitor] leave this area, the zoo or this exhibit learning A, B & C. But you can take any path to achieve that. Yeah, I really like that.

Since his initial years of teaching, he has used this approach to shape how he structures teaching and learning in his classroom. He develops multiple modes and pathways for his students to achieve the learning outcomes that he plans. He positions himself as a coach and mentor, "I want to stay on the side. I don't want to be a heavy-handed teacher," Mr. V's way of saying that he'd rather be the "guide on the side" than "sage on the stage." Because this kind of structured informal learning is central to Mr. V' identity as a teacher, he makes use of a variety of resources at hand to shape and enable student-centered and self-directed learning.

His teaching and learning, although structured by standardized tests, affords flexible learning spaces for his students and multiple ways of engaging in science. He has a penchant for leveraging the ways that adolescents engage in their worlds in the classroom. For example, Mr. V painted old lab tables with chalkboard paint and rendered writing on the desks as a legitimate learning activity in his classroom. In between the random doodles and graffiti tags are scribble and sketches of Earth science concepts. Similarly, he uses "tagging" as a review activity; students use dry-erase markers to draw their understandings on the windows and engage in gallery walks to learn and review from each other's drawings. A number of videos that Mr. V posts about his classroom on Facebook shows students singing and one in particular, a student going back and forth between playing on a synthesizer and working with his group. Amidst these activities, students also demonstrate engagement in science by breaking verse to ask a salient question or moving to another table to help out classmates. These actions in the classroom convey a strong sense of mutual trust, which is important in generating success in any learning environment, physical or digital.

Centering Trust

The activities that Mr. V enacts in his classroom serve not only as a means for students learning but also a way to build solidarity and trust in the classroom that is critical in student success. Developing trust in in the classroom is a critical and often underemphasized aspect of learning to teach. The relationships that teachers build with students are just as important as the quality of the subject taught (Id-Deen & Woodson, 2016). Mr. V emphasizes relationship building with his students,

> Every kid that comes into my class, I have a dialogue with them. I have a relationship with them…you know, I meet them at the door and I greet them. And at that very instant, whatever, whatever they choose to respond with me, I know we're going to have a smooth day. I

> know the student is either having an issue with something and I got to find out. The faster I find out what the issue is, if they're hungry or … if they didn't sleep or if they have to work,…then I have to fix that issue because once I get rid of that distraction and fix that issue, then the rest of my class, rule, management and instruction, becomes smooth and that student buys in. Because they know I care. They know they can talk to me.

Catherine Ennis and Terri McCauley note, "Trusting environments are best created in classrooms in which students and teachers can work co-operatively over an extended time-period to construct trusting relationships" (2002, p. 151). In the classroom, trust extends beyond the socioemotional safety and towards a belief in all students' abilities; that all students are capable of learning. Id-Deen and Woodson (2016) found that the absence of trust negatively affects learning. Creating a trusting environment includes rigorous learning opportunities, creative teaching and learning strategies and allowing for on-task dialogue. Trust also includes allowing students to take ownership of their own learning; Mr. V describes his alternative to station teaching, "I do a café type model where I construct alternative, four different paths for the students to go through the stations because determining what they answer to the do now, their path is constructed." He is also transparent in his grouping as he lets students know why they are grouped the way they are grouped and follow the path that they follow through the stations. Likewise, he structures the cafés so that once higher performers finish, they move to a path where they help the lower performing students,

> because if my lower performing students display an understanding or mastery of the concept we are reviewing, or we are going to do or even forward thinking on that concept, then I know that I am going to have a successful lesson…because then I can assume most of my students understand it.

In Mr. V's classroom students play a central role in helping their peers and this something that he frequently reinforces by reminding them that in his class, "we all help each other out." In a video Mr. V posted on Facebook he noted, including a jab to the *Danielson Framework*, "[This is what] highly effective teaching looks like; I didn't say one full sentence that whole class. Students lead work and explain concepts; help each other. Everyone here did amazing," also describing how he allows students to play in his classroom; playing helps them to stay on task.

Interaction Rituals and Learning

The video that Mr. V posted demonstrated the entrainment and corresponding solidarity in his classroom. The students were freely moving around to different tables and while there was "off-task" joking, it was clear that the students remained on-task and that the joking contributed to the playful atmosphere that kept the students engaged and focused. Mr. V allows his students the freedom to engage in learning in ways that resonate with who they are as learners and how they wish to engage in the tasks at hand. These activities serve to generate consistent positive emotional energy, an emotional state of feeling empowered, confident, and agentic (Collins, 2004; Seiler & Elmesky, 2007), in the classroom, which in turn contributes to productive science learning.

Kenneth Tobin and colleagues extended Collins' (2004) notion of Interaction Ritual Chains (IR) to science teaching and learning. Through research and enactment of successful science teaching in urban schools, they established that the generation of positive emotional energy through social interactions is important to successful classroom teaching and learning, "if a teacher can be involved with the creation of chains of successful encounters then rituals can occur with which participants can associate positive emotions, just by thinking back on the activity" (Tobin, 2007, p. 15). This perspective also articulates the importance of mutual respect, collective effervescence, affiliation, and solidarity in student success. Olitsky (2007) describes:

> Emotional Energy is generated through successful interaction rituals that are characterized by bodily co-presence, mutual focus, common mood, boundaries to outsiders, an "entrainment," or coordination of body movements and speech, shared experience between participants on both an emotional and cognitive level and solidarity with others present (p. 8).

While much of this work was done in face-to-face context, reflecting on the emotional component of interactions in CrossActionSpaces will be important in describing learning in the digital age. Mr. V's identity as an informal science teacher who values student-centered, multimodal learning also shaped how he used WhatsApp in his teaching. He incorporates this resource for a very specific goals—student success on the standardized tests—yet maintains the culture of trust and peer-learning that characterizes his classroom. As I will demonstrate, the evidence of successful interactions and positive emotional energy was very specific to this communicative space but transcends the boundaries of the digital space into a CrossActionSpace that incorporates the physical and temporal classroom, and the ephemeral conceptual and digital spaces that are integral to the lived experiences of Mr. V and his students.

Extending Interaction Rituals to CrossActionSpaces

> So, WhatsApp is a chat app right, where you can create a chat room within the app and you can download it. And what, how I've been using it is that I'm letting the students access me outside of school. So when I'm home if they have a question about homework or a concept we did in the morning or during lessons, they can ask me. Um, all the students, not all, I'm sorry not all, there is about thirty students in the room. I gave my number to all of the students but not everyone downloaded the app to message me. And I don't force them to. And I review the concepts and WhatsApp allows me to do a number of things. It allows them to have access to me at anytime of night. It allows me to send them videos from my house while I am going over the concept with them, while I am going over the concepts I direct the video. Because in my room [at my house] I put whiteboard paint so I can draw things while I am talking to them. Or write, while I am talking to them and explaining. Um, and then they have dialogues with each other, sharing [re]sources. That's how I've been using it in my class…Because that is the only time they get this instruction…because they don't have good study habits so this gets them exposed more to me and my content when they are outside of my classroom.

For Mr. V, the classroom does not end at the finish of the day and at the boundary of the physical plant. Rather the classroom goes beyond these temporal and spatial borders with WhatsApp. Mr. V recognizes the challenges that his students have to maintaining good study habits at home and views his role as ensuring that they have a space to develop and hone productive study habits with his guidance. He views this tool as a means for his students to access the additional help in science outside of school time and as a way of deepening his personal connection with his students. Although research on the use of WhatsApp in teaching and learning contexts is emergent, researchers have learned that WhatsApp provides a useful platform for connecting students during out-of-school time. For example, Nirgude and Naik (2017) have described it as an effective tool for sharing information, engaging in discussions, assessing learning, and offering feedback. In another study, Sayan (2016) found that WhatsApp use contributed to student achievement on exams with both the instant knowledge and using the media as motivating factors. Bouhnik and Deshen (2014) interviewed secondary teachers about their use of WhatsApp in the classroom and learned that the technology served four purposes: communicating with students, nurturing social relations, creating dialogue and encouraging sharing among students, and as a learning platform. These findings indicate that using social media platforms, such as WhatsApp, in education has promise for extending the learning environment of the classroom beyond the school both in time and space. While these studies have examined the features that make WhatsApp conducive to teaching and learning, they did not examine the dialogues that contributed to learning, including the social relationships that are critical in maintaining a safe, trusting and effective learning environment within the WhatsApp interactions.

In the following sections, I present several dialogues from Mr. V's WhatsApp interactions with his students and describe the ways that these dialogues contributed to the solidarity and positive emotional energy in the group. I highlight the features of the dialogues, as they emerged in the app, that extend the solidarity that characterizes Mr. V's physical classroom and contributes to successful science learning among his students.

Collaborative Learning in WhatsApp: A Low Stakes Environment for a High Stakes Review

In early June, Mr. V established a WhatsApp group entitled State Exam Prep[1] he included me in the group because of our relationship in the Collaborative. It began with a series of him adding students' phone numbers to the group interspersed with emoticons and greetings like "Yoooo" and "Whassup" from students

[1] In the USA, different states have different policies regarding standardized exams and secondary school graduation requirements. In the state where this study took place, secondary school students are required to take and pass subject-area state exams, including Earth science, in order to receive a high school diploma.

acknowledging their admittance into the group (on my end, I did not realize that I was added to the group. I just suddenly received an influx of notifications from WhatsApp with each student addition and greeting. It was not until Mr. V texted me separately about the group did I realize what was happening). Greetings perform a critical role in the establishment and maintenance of social relationships (Li, 2010), so the greetings in the WhatsApp was the first step in marking this virtual space as an extension of the relationships developed in the classroom. Some of the greetings were general to the whole group whereas others were specific either to the teacher, "Whassup Mr. V" or student-to-student, "hey girl." Although the participation in the group was voluntary and the review happened in the evening, there were an impressive number of students involved as indicated by unique colors and phone numbers in the app. In the representative dialogues, I used the last four digits of students' phone numbers to signify the different voices.

Each evening was for the review of a different Earth science topic. Mr. V established the ritual of sending out an IM letting students know that the first video would be posted at 7 pm so that they could anticipate the session. (In one of the sessions a couple of students entered the space early, around 6:45 and were quickly reminded by Mr. V and others of the first post time ritual). The video was usually an explanatory video of a topic covered in class during the prior year and would be on the State Exams. The culminating post was often a picture of a review sheet with sample questions from the State Exams. In exchange for donuts, Mr. V asks them to submit the questions directly to him by 6 am the following morning. Mr. V also posts questions during his review for students to answer and discuss.

The communicative style in the WhatsApp is very informal. The text includes slang, typos, phonetic spellings, and creative uses of grammar as well as hegemonic English. Similar to in the classroom, Mr. V and his students seamlessly code-switch between hegemonic English and vernacular English (and there is a digital English that seems to be more related to spoken vernacular English; in addition to emojis, it includes abbreviations and phonetic-like spellings that appear to be used to convey speech emphases); these fluid changes in speech structures allow for the attenuation of borders between the classroom and the surrounding community and establish a sense of community within the classroom. Being able to communicate freely in students' (and teachers') home and school languages also serve to solidify the trust and social bonds in this virtual space. The use of the emojis is also a key feature in the WhatsApp communication and serve as sources of entrainment among Mr. V and his students.

In the following exchange, Mr. V presents the hydro[logic] cycle through a series of short, informal videos. The post is followed by sample State Exam questions followed by "enjoy" and a smiley emoji. This signals to the students that this is a low-stakes space with the purpose of helping them to pass the exams,

3603	Okay So The Water From Underneath The Ground Is Causing The Run Off Why Does It Start Specifically In That Area?
Mr. V	– [Answer runoff video] – [Diagram hydrocycle] – [Scan of test questions] – And here are the regents questions enjoy [smiling emoji]

Students immediately followed with questions about key terms and queries about where to submit their answers. Mr. V jokingly responds, which is followed by two laughing students,

9230	– What's percolation?!? – Do we post our answer's in the group?!! Rn
Mr. V	Send me the answers in a private msg so M won't copy them [two laughing emojis]
9230	Dwl[a] ohk
3603	– [Three laughing emojis] – What does permeable mean?

[a]Dead wid laugh

Another student posts screen shots of definitions of the word in question, Mr. V praises the group, "I love it when you help each other out." More joking happens and the entrainment of the laughing emojis ensues,

5576	– [screen shot definition of permeable] – [screen shot definition and diagram of percolation]
9230	Thank uh
Mr. V	[2:50 min video of him explaining permeability using the whiteboard]
3603	Thank you
Mr. V	– [Two laughing emojis] Good job [5576] [three laughing emojis]
5707	I couldn't respond to anything right now because I'm trying to watch your vids [sad emoji]
Mr. V	It's ok [ok symbol emoji] just focus
0357	Did I get the answers right??
8177	So when the soil is saturated run off occurs??
5707	Yes.
Mr. V	[Smiling emoji] I love it when I see you all help each other
6656	Can we help each other on the [State Exams]?
0530	[three laughing emojis]
Mr. V	[five emojis]
3603	I'm Dead [laughing emoji]
8177	[two laughing emojis]
3507	[two different laughing emojis]
9633	[one laughing emoji]
7165	[three laughing emojis]
5707	Is everybody going crazy here?!?
Mr. V	N my buddy we just bonding and working on [State Exams] and happy we Getting it done
4083	[Sideways laughing emoji]

As testing is usually a source of stress and anxiety for students this series of laughter serves as both a release and the generation of positive emotional energy. The emojis signal a collective effervescence indicative of successful interactions

(Ritchie, Tobin, Hudson, Roth, & Mergard, 2011). Mr. V even articulates this feeling when he writes, "we just bonding and working…and happy we getting it done."

In the following exchange, the students review their answers to the questions. There are consolations and discussions about reasons for the wrong answers and collective praise for the right answers. These are also factors that demonstrate group solidarity, as the students are able to console each other's failures and celebrate successes. Mr. V "contributed" a reward to this exchange, but the affective factors, including positive emojis (smiling and clapping hands), of this exchange were student-to-student. Furthermore, the students feel a level of trust and safety in being able to share their "failures" without fear of being ostracized by Mr. V or other classmates. In this learning space, the students' agency changes as they take more ownership of the direction of the learning exchanges and Mr. V's role is configured differently from that of the teacher to that of a facilitator, which resonates with the way that he desires to be as a teacher. In the segment below, one student lamented about getting one wrong that was consoled with "hushies" from another student showing that there was a certain degree of care for her classmate,

5791	Well i got number 2 wrong the answer is (3) because permeable it the ablity to allow the soil soak in water
Mr. V	So impermeable means to not soak up water …
5791	Yes
9230	I got all right [clapping hands and smiling emoji]
8177	[Clapping emoji]
9230	Yesh lexiie
Mr. V	When every one does the days work and vids you get a reward
6656	Everyone
8177	I got one wrong [sad emoji]
9230	Hushies.. You'll get it next time
7620	You guys are so motivational
9230	[Two winking emojis] Thanks [7620]
0764	Anyone pree I did the homework
9230	We got homework [rolling eyes emoji]
3603	Got job [0764] [shout out emoji]
0764	Thank you [grateful emoji]

Another interaction demonstrates a breach of trust when one student wanted Mr. V to confirm his answer rather than his classmates,

3174	Ya
3043	I want Mr. V to tell me that I'm right just to be sure [thinking emoji]
Mr. V	Ur rite
3174	[three angry and three steaming emojis]
3043	[grateful smile emoji]
Mr. V	Red shift only

3043	– Got you – Copy
Mr. V	– We are here to help each other [3043] – Listen to them
3174	[two angel emojis]

Although several of his classmates said “red shift,” which was the correct answer, he still wanted confirmation from Mr. V. This was met by angry emojis from one of the students who posted the correct answer. Mr. V reminded them of the class culture, which was followed up with angel emojis from the same student who displayed annoyance at being ignored.

In this low-stakes environment, students are also more motivated to work out the science problems themselves rather than getting the answers from others. Mr. V creates a positive culture of learning and achievement in his practice, which extends to his students wanting to learn science and wanting to do well. In the exchange below one student in particular got upset when another did not follow the instructions of submitting the answers directly to Mr. V,

Mr. V	All answers are due by 8:15 today’s a easy day [heart and globe emoji] if you can’t submit by then -I send u a different vid
9230	– I feel soo smart I got everyone right [three tears-of-joy emojis] – Im soooo happy – Everything*
8177	Nice
5707	39 is 3) 12.5 hours!
9230	Private
5791	So you aint see the “send me the answers in a private message”
5707	−46 is 1) 11m! −47 is 4) perigee and a Full-Moon phase!
5791	[5707] SEND HIM A PRIVATE MESSAGE
5707	How am I gonna do that
5791	– Your not giving everyone a chance to figure it out on they own r u blinddd?! – Text him on whats apps duh – Just like everyoneee else

The conversation continued with 5707 apologizing, another student chiming in, “It’s Okay [5707] I Made That Mistake Too,” before there was a collective instructional on how to send Mr. V a private message. With the negative emotional energy building as the two students continued the heated exchange, Mr. V interjected with a humorous diffusing video of himself which elicited laughter from the students,

9230	[five laughing with tears emojis] am dead
8177	[Skull emoji]

A student even made a screenshot of a funny face Mr. V made during his video and shared it with the group. This was followed by more laughter and "dead" signaling a redirection of the energy in the group. According to Olitsky (2007), "during successful interaction rituals, the symbols that are both created and exchanged become invested with positive emotional energy and can be used later to generate successful interaction rituals with others who find these symbols similarly charged" (p. 36). This screen shot became symbol that reemerged at random times during different sessions, eliciting laughing emojis and dead symbols (as in "dead with laughter") from the group each time. It was a recurring resource for eliciting collective effervescence and positive emotional energy and reinforced the solidarity in the group. These small symbols produced successful interactions as well as reinforcing the overarching symbol of achieving in science and being successful on the State Exams. The symbol of success brought the students to the WhatsApp reviews each evening and the symbols that emerged during the chat encouraged them to stay.

From the initial interactions on WhatsApp to the final weeks of the review, about 3 weeks, the emotional energy in the chats largely remained positive and supportive. Mr. V and the students managed to quickly diffuse disagreements that arose. This review and this space were important for the students and they made the collective effort to keep the space focused and positive. The irony to me, as an outside observer to this chat, was that many of the students were not fully aware of who all of the others were in the chat until a few sessions into the review (in WhatsApp some of students used their real names whereas many used nicknames). Mr. V explained to me that there were several sections of the same class in the chat, so not all of the students knew each other. During a session about a week into the reviews there were a series of "who's who" exchanges to identify those with unknown nicknames and students from different sections of the same class. This is evidence both of the trust that the students have in both Mr. V and each other that they could enter this space of "strangers" and fully engage in the learning processes without fear of being humiliated for being "wrong" or "failing."

Configuring a Culture of Collaboration with WhatsApp

The WhatsApp communication allowed for multimodal engagement in science learning that included learning the science content and processes as well as solidifying social bonds around science. There was a strong emphasis on solidarity building through joking, emojis, and collective encouragement along with admonishments when the social norms of the class were broken. Both Mr. V and the students created and sustained a strong culture of positive emotional energy around science learning. One student even joked about hating school, in order to see the reactions from the group knowing that hating school was counter to the learning culture of Mr. V's classroom,

3174	I really hate school [four angry and three steaming emojis]
9230	Dwl why
5707	That means you ain't never gonna be smart!
3174	– Im jk i just wanted to see yall reaction [two cool emojis] – [two big smile emojis]
5707	If you hate school, you'll never be intelligent in the future! School is important in life!
3174	Yea
Mr. V	Yes you see in my class I teach science but always about life
5707	Are we ready for your vids, Mr. V
6656	[two laughing emojis]
3174	– Its 7 no – Now*
5707	I'm ready! [three star emojis]

"Online encounters…are…constitutive of an ensemble of encounters that comprise our various relationships in and through the real and the virtual," in their research on WhatsApp usage O'Hara, Massimi, Harper, Rubens, and Morris (2014) describes a CrossActionSpace; the social relations therein are reflective of the relationships that we develop in our various and intersecting life spaces. They describe it as a digital age dwelling, "human affairs entail a movement through and between sites of engagement, where trajectories of individuals intersect and create a texture of joint being together, a felt-life of sociality" (p. 1133). In CrossActionSpaces the divide between the virtual and physical are dissolved and learning cultures are transcendent. The WhatsApp space decentralizes power in teaching and learning and affords students agency in how they direct the learning space. There is a distributive sense of agency where both participating students and Mr. V share responsibility for the collective learning, the generation and maintenance of positive emotional energy and a collective solidarity towards success on the defining exam.

As a critical agentic bricoleur, Mr. V extended his classroom into the digital space of WhatsApp, where science learning is a part of the social activity, one in which both the teacher and students look forward to engaging because of the positive emotions it generates. It is the reiteration between the interaction rituals (the consistent time of the group meetings and starting with videos and exam questions, dialogue exchanges that extend the informal nature of communicating in the classroom into the digital space and collective emoji use to signify positive and some negative exchanges within the dialogues) and trust that make the WhatsApp space a successful learning space as an extension of Mr. V's classroom. Through these modes of interacting, the students configure this as a social space and the symbols contextualize the students they connect with Mr. V, each other and to the science content and exam. The symbols created in the classroom tranfer into the WhatsApp space and contribute to the success of this space in achieving goals of student science learning.

Both Mr. V and his students identities are shaped by the learning culture in the CrossActionSpace that intersects their classroom, community and the digital spaces in which they live. Through the shaping of the WhatsApp space to afford youth agency in shaping the direction of the learning interactions, Mr. V creates a resource for the students to develop positive identities around school learning, science and academic success; identities that are often not available to urban students of color (Nasir et al., 2013). As a teacher, Mr. V's identity as an "informal teacher" compels his agency as a critical agentic bricoleur to develop and maintain learning spaces where his students choose their own path to learning and drive themselves and each other towards science/academic achievement. In the case of both Mr. V and his students, the agency developed in this CrossActionSpace is transcendant and created the conditions for all participants to develop identities that were resonant with imaginations and realizations of academic advancement.

Mr. V's teaching philosophy drove how he configured this digital space for his classroom. He created the conditions for trust and solidarity in his classroom that extended to his use of WhatsApp; and the affordances of WhatsApp allowed for an extension of Mr. V's culture of collaboration. As a social media application, WhatsApp has key affordances that make it a salient resource for transcending a physical classroom space. It is a free app. With the widespread use of smartphones in everyday life, this app is available to everyone and affords rapid and asyncronous or syncronous communication between users. Mr. V scheduled a time, and many students were "present" to participate in the review. However, the dialogues and videos remain in the space allowing latecomers or those who could not make the review to still benefit from the learning discussions that occurred. This application allows for multimedia communication—photos, videos, voice message—which is salient for education. In this space, Mr. V employs a cogenerative and emergent version "just-in-time" teaching (i.e., Novak, 2011), where there is a simultaneous production, assessment, and reproduction of knowledge. Mr. V introduced materials in this space, of which some students had some prior knowledge, and students' responses immediately alerted Mr. V to thier levels of understandings and gaps in knowledge that needed to be addressed. Because WhatsApp is multimodal, Mr. V was able to immediately able to produce resources to meets students' learning needs. This is not always possible in the classroom with set lesson plans and curricula and rigid time structures that often impede flexibility in teaching. The flexibility of this CrossActionSpace also afforded the students agency in determining the direction of the sessions; spending more or less time on a given topic depending on their satisfaction with their levels of understanding, which was uninhibitively expressed with emojis. Although Mr. V initiated these spaces with the goal of improving his students' chances of success on the State Exams, the space always and immediately became a cogenerated and collaborative space of learning. Mr. V and his students were equally invested in community building and science knowledge production. In an urban school that was often plagued with low test scores and disinterested students, Mr. V and his students created this space where science learning and success was a critical and collective goal.

Conclusion

In the twenty-first century teachers have access to numerous digital tools for communication and collaboration. Not only are these tools being rapidly developed, but they have augmented teachers and learners ways of interpersonal communication and relating. While we readily use these tools in our day-to-day interactions, applying these tools to teaching and learning settings would go a long way to blurring the boundaries between schools and community and allowing for more informal interactions not only to contribute to classroom knowledge production but also in fostering the emotional bonding that is necessary in creating safe, trusting, and effective learning spaces.

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Chapter 8
"Wow" and Then What? Tablets in a Conservative Polish School: Mapping Emergent Teaching and Learning Practices in the Classroom

Lucyna Kopciewicz and Hussein Bougsiaa

Abstract This chapter contributes knowledge and new insights into learning and teaching practices in two classrooms in a Polish primary school that were observed over a longer perspective of three school semesters. Although the research project was performed on a small scale, it can be defined as one that monitors the changes to learning and teaching practices happening in the traditional educational culture of the school under analysis. In particular, these changes were identified through the data collected by means of classroom video ethnography and interviews with classroom's teachers. The chapter contributes a map of teaching and learning practices over the course of three semesters during the process of introducing tablet technology into a school and a series of conflicts and tensions teachers experience in their tablet-mediated teaching practices. The "wow" in the title of this chapter is tantamount to the teachers' excitement, hope, and their expectation that the appearance of tablets at school will work "wonders." The teachers perceived tablets as a magic wand about to cause radical changes to teaching and learning practices. However, nothing like that happened. Our video ethnographic and narrative research, trying to find optimum ways of tablet integration in the classroom, started at the moment when the teachers expressed their great disappointment and began to wonder "and then what?"

Introduction

In recent years, an increasing number of research studies explored the potential and the outcome of the use of mobile technology in schools. In Polish educational research the mobile technology integration in school classrooms is considered an

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obvious modernization milestone. These studies focused on learning efficiency, improvement of learning outcomes, and students' motivation (Hojnacki, 2011; Lewowicki & Siemieniecki, 2012) The research works approached technology as a "supplement" to the established teaching and learning practices used for the purposes of the traditional educational goals.

Another type of research works explored the potential and implications of new tools and the new materiality for everyday teaching and learning practices (Cerratto Pargman, Jahnke, Damsa, Nussbaum, & Säljö, 2017; Jahnke, Bergström, Mårell-Olsson, Häll, & Kumar, 2017; Säljö, 2010) the transformation of pedagogy, and the shaping of new digital competences, and twenty-first century skills such as creativity, critical thinking, ability to draw conclusions, data processing, interdisciplinarity, ability to cope with information and online resources, intercultural competences, project thinking, or virtual cooperation (Pegrum, 2014). Polish education research works assumed that the new material conditions for tablet-mediated teaching and learning may be a challenge to the traditional transmissive, frontal teaching model dominating in schools, and may give rise to conflicts between traditional and emergent new learning and teaching practices (Dylak, 2013). Our research is related to the last type of assumptions.

Theoretical Framework

In this chapter, our research interest is focused on the relationship between tools and teaching/learning. To put it more precisely, we adopted an assumption that the classroom teaching and learning practices are rooted in specific materiality. Changes in the materiality and the appearance of new educational tools may affect the practices and cause tensions or conflicts between the existing traditional practices and the emergent new practices (Cerratto Pargman et al., 2017).

For this research, we chose the micro-perspective of school analyses (Meighan & Harber, 2007), which allows us to identify and name the changes emerging in connection with the new educational materiality.

Many leading educational researchers describe the Polish education as conservative (Dylak, 2013; Klus-Stańska, 2011, 2012; Kwieciński, 2012). The conservatism does not apply to the teachers' personal beliefs or the values dominating in the Polish society. It is a generally adopted way in which the education system functions, as shown in the executed educational goals, the assumed roles of the teacher and learner, the selection of educational resources, assessment practices and control. The conservatism is also an internalized attitude of the teachers, which manifests itself in their reflections about good teaching and learning, and materiality in which they are achieved.

Referring to the sociological model of conservative education (Meighan & Harber, 2007), we adopted the following elements stressing its dominating features and deviations from it (i.e., transition towards the progressive model of education):

- *Type of educational goals adopted*: from knowledge transmission (conservative education) to knowledge generation (progressive education)
- *Type of learning practices executed*: from passive adoption and consolidation of knowledge and skills (conservative education) to active search for and generation of knowledge in group processes (progressive education)
- *Use of didactic resources*: from focus on the textbook as a source of real school knowledge (conservative education) to accepting many varied sources of knowledge in teaching (progressive education)
- *Learner’s role*: from passive reception of knowledge, “listening and memorizing” (conservative education) to active generation of knowledge “negotiation and testing” (progressive education)
- *Teacher’s role*: from dominating expert (conservative education) to companion and observer of independent learning (progressive education)
- *Assessment and feedback*: from the absence of feedback and unclear grading criteria (conservative education) to informative assessment and clear, publicly announced grading criteria (progressive education)

Meighan’s model was also supplemented with the Substitution Augmentation Modification Redefinition (SAMR) model (Puentedura, 2014), which have focused on stages of technology integration and its ability to transform the existing teaching and learning practices.

Tablet integration may lead to new opportunities for teaching and learning within the classroom and the need for teachers to rethink and redesigned their pedagogies. We used the follow-up interviews with teachers to document how teachers make use of tablets in their classrooms and categorize the types of teachers’ conflicts and tensions concerning the emergent teaching and learning practices (i.e., reflections about their pedagogies and didactical design in practice) in new materiality. This was an additional component of our study.

Our study has investigated the following research questions:

RQ 1: What is the map of teaching and learning practices over the course of three semesters during the process of introducing new technologies into a school?
RQ 2: How do teachers define new technology-related conflicts and tensions in their teaching practice?

Together these three elements have covered our empirical study design (Table 8.1).

Research Design and Methods

In order to broaden knowledge about emergent practices in the tablet-mediated classroom and how they change over time, we conducted empirical research in a primary school located in a city in the region of Pomerania, northern Poland. The research was part of a project supported by the National Science Centre in Poland,

Table 8.1 Empirical study design

Theoretical framework	Research questions	Research methods	Unit of analysis	Goal of analysis
Meighan's model SAMR model	RQ1	Video ethnography: the recorded classes	Observed teaching and learning practices	Identification of the emergent changes in teaching and learning practices
Teachers' reflections about their pedagogies and didactical design in practice	RQ2	Narrative: The follow-up interviews with teachers	Teachers' discourse: conflicts and tensions concerning teaching and learning practices	Identification of conflicts and tensions at the particular stages of didactical design in practice

and its aim was to describe and analyze emergent teaching and learning practices in a classroom enhanced with mobile technologies.

Context of the Study

The school we studied was chosen because since 2015 it invested in wireless internet connectivity and purchased Air iPads (with their own financial means) that were to be used as part of the 1:1 model. The school director invited the authors to diagnose the sources of problems associated with using the tablets during classes.

For the purposes of our research, we selected teachers who volunteered to conduct classes using tablets. They are all women and their professional teaching experience ranged from 2 to more than 20 years. In this school, women constitute more than 90% of the teaching staff. A detailed structure of the sample is provided in Table 8.2. The subjects represented various school subjects and domains of knowledge.

Teachers were informed about the procedure, conditions and timing of the empirical research. The collection of empirical data began in September 2015 and was completed in December 2016. The qualitative approach of video ethnography was selected as the leading one in our research. The interviews with the teachers whose classes were recorded were a source of significant supplementary data. The interviews were conducted after each semester of filming session (i.e., one interview per semester; see Table 8.3).

Data Collection Methods

We participated in the collection of more than 60 classroom observations documented with field notes and videos showing lessons (more than 60 h of video material) over three school semesters. During this time, the same groups of

Table 8.2 Sample structure—teachers

Teacher symbol	Age (years)
T1 (mathematics)	59
T2 (Polish)	58
T3 (IT)	45
T4 (English)	34
T5 (science)	29
T6 (religion)	27

Table 8.3 Data collected at school divided into school subjects, grades, and semesters

	Semester 1 2015/2016	Semester 2 2016	Summer holidays (→)	Semester 3 2016	Grade
Video ethnography:					
Total hours of observations Divided among: Mathematics Polish IT English Science Religion	22 h 4 h 4 h 4 h 4 h 3 h 3 h	22 h 4 h 4 h 4 h 4 h 3 h 3 h		19 h 4 h 4 h 3 h 3 h 3 h 2 h	Grade III → IV and grade IV → V
Interviews with teachers of:					
Mathematics Polish IT English Science Religion	1 1 1 1 1 1	1 1 1 1 1 1		1 1 1 1 1 1	They teach in the same grades in which the video ethnographic research was conducted

learners and the same teachers were observed, which made it possible for us to maintain a certain continuum and to document changes in teaching and learning practices (Derry et al., 2010).

The interviews with teachers were conducted in Polish. Each interview was recorded and transcribed. Excerpts of the interviews were translated into English for the purposes of this chapter. Data that could facilitate the identification of the teachers were anonymized.

A detailed review of the data collected divided by semesters, grades, and the analyzed groups of school subjects is presented in Table 8.3.

Operationalization of the Adopted Theoretical Models: Developing Coding Schemes

We had two types of empirical material at our disposal:

- Substantial video material showing objective practices of teachers and learners in the classroom (practices);
- A corpus of narration related to the teachers' reflections about their didactical design in practice, experience, understanding and assessment of tablet-mediated learning (discourse).

The coding scheme originated from the Meighan's model extended in the SAMR model, from which the names of the analyzed categories were taken (from A to G). Then, based on knowledge of the stages of transition from conservative (transmissive) to progressive education and the possible stages of the integration of technologies in the classroom, values on a scale from 1 to 5 were assigned that symbolized identifiable and separate ranges of the practices of teachers and learners and how technology was used during classes. The lowest values (1 and 2) corresponded to the transmissive (conservative) logic of the Polish school with its concentration on "closed" knowledge, and textbook and memorization related actions. In these contexts, technology was clearly imposed on the order of the transmissive orientation of the Polish school. The value 3 referred to transition attempts at stepping beyond the transmissive school logic in the analyzed scopes of practices, although, at the same time, it was marked by high teacher pressure and increased control (as expressed in the teacher's frequent messages such as "you must" and "you must not"). Values 4 and 5 referred to the construction of learning situations outside the framework of the transmissive, conservative logic of the Polish school. These were attempts to create learning situations that engaged the cognitive curiosity of the learners, their independent thinking and analytical skills and cooperation in groups. Therefore, we were dealing with attempts at the bottom-up construction of an alternative progressive learning model in which technology played a significant and indispensable role.

A larger research team discussed both the shape of the seven main categories and the defined areas of possible variation within categories. When determining an area of variation, the team ensured that the values related to the clearly identifiable scope of the practices observed; in other words, the values from 1 to 5 expressed the separateness of practices and not intermediate states that could be interpreted variously in further stages of analysis. The coding scheme containing the area of variation of the observable practices is represented in Table 8.4.

Methods for the Analysis of the Narrative Data

We applied qualitative thematic analysis to process the interview data and focused (in compliance with the adopted theory) on the conflicts and tensions verbalized by the teachers. The interviews were open discussions between the us and the teachers about

Table 8.4 Coding scheme adopted for video ethnography

Category	Description of the coding scheme adopted
A. Type of educational goals adopted	1. Unclear, coverage of the lesson topic 2. Provision of knowledge, consolidation of knowledge/skills 3. Search for information and its use within the framework defined by the teacher 4. Search for information and its independent processing, recontextualization, etc. 5. Production of knowledge in a new form/shape
B. Type of learning practices executed	1. Individual viewing of illustrative materials (presentation prepared by the teacher) 2. Individual/group exercises, consolidation of skills 3. Individual/group activity consisting of reorganizing knowledge under the teacher's control 4. Group activity consisting of processing knowledge autonomously from sources indicated by the teacher 5. Group activity consisting of processing knowledge
C. Use of didactic resources	1. Domination of textbooks; tablets used for displaying materials 2. Domination of textbooks, applications closely subordinated to textbook material 3. Breaking textbook monopoly through a multitude and variety of applications 4. Breaking textbook monopoly through applications designed to reorganize knowledge 5. Use of applications for producing knowledge and balancing textbook knowledge
D. Learner's role	1. Recipient of ready educational content 2. Exercising and consolidating supplied knowledge and skills (memorization) 3. Reproducer of educational content with elements of independent knowledge processing using an indicated source 4. Reorganizing knowledge, transforming and group negotiation of knowledge, opinion expressing skills 5. Group transformation of knowledge, independent search for materials and information and assessment of sources, cooperation with and involvement in the learning team, negotiating ways technology can be used
E. Teacher's role	1. Expert, controls short time of activity with tablet through additional procedures 2. Expert, limits tablet use time and controls the correct use of applications, provides technical support if necessary 3. Expert-controller with elements of facilitation, supports learner involvement, provides substantial and technical support to learners, strong relationship of control of the learning process 4. Consultant, monitors subsequent stages of group work, provides feedback 5. Companion, observer (mentoring elements) of the learners' independent actions

(continued)

Table 8.4 (continued)

Category	Description of the coding scheme adopted
F. Assessment and feedback	1. No feedback, no assessment 2. Comments concerning lessons, a general summary 3. Assessment addressed to an individual or group concerning the result of work 4. Assessment and feedback during particular stages of individual or group work and after the end of work 5. Assessment criteria announced at the beginning of classes, feedback at subsequent stages of work, assessment after end of work, elements of advisory assessment
G. Educational goals in connection with the role of technology	1. Making knowledge transmission more attractive 2. Substitution—streamlining 3. Extension—improvement 4. Modification—considerable change 5. Redefinition—transformation

the recorded class, and one of the questions posed referred to the conflicts and tensions the teachers were experiencing with integrating technology into their classrooms. During analyses, only those conflicts and tensions that were mentioned by all of the teachers in a given semester were taken into consideration. Thus, the criterion of the strength of the conflicts and tensions between traditional and new emergent teaching and learning practices that appeared in a given semester of the research was applied.

Coding Procedure

Video Ethnography Material Collected

Every hour of the material viewed consisted of a recording of one lesson. After watching it, we coded it based on the list of categories (A–G) ensuring that the code selected best represented the character of both the recorded material and the actions observed. We performed the coding independently, which increased the reliability of the process. With a very few exceptions when there were differences in the code ascribed, we agreed on a common ground and introduced corrections. This referred to just four videos from category A.

The analysis of the video ethnography material was performed using the following four steps:

- Applying a coding scheme to all the video material.

  This step resulted in ascribing code values to each video of each teacher.

- Calculating the median values in the particular categories for the particular teachers for each semester (from I to III).

By maintaining the division by semesters, we obtained three collective tables (one for each semester) that present the median values obtained by the teachers (Table 8.5).

Table 8.5 Median values obtained by teachers in the first semester (I)

Teacher	Number of observations	Median values obtained by teachers						
		A	B	C	D	E	F	G
T1	4	1.5	2	2	1.5	2	2	2
T2	4	1.5	2.5	2.5	2.5	2.5	2	2
T3	4	1	1.5	1	1.5	1	1.5	1.5
T4	4	2.5	3	3	2.5	2.5	2	2.5
T5	3	1	1	1	1	1	1	1
T6	3	2	3	2	3	2	1	2

- Placing median values obtained by teachers on diagrams for each semester.

The next step of the coding scheme was to place the calculated median values on diagrams representing the three semesters during which our research was conducted. The first comparisons were also performed; initially, the areas of the most and least considerable changes in the observed practices of the different teachers were identified.

- Analyzing transformations in teachers' practices.

Before performing analyses for this dimension, we determined the thresholds of the median values defining the boundaries of the orders in which the teachers' practices were located.

We identified median values between 1 and 2 as practices representing the order of the transmissive school. Here we saw confirmation of the values of the heretofore existing culture of education in which technology is strictly subordinated.

We defined median values ranging between 2.5 and 3.5 as tension areas that were part of the existing culture of education and in which the first serious "cracks" appeared in its practices where new teaching and learning practices were emerging.

We recognized mean values ranging between 4 and 5 as symptoms of the culture of education experiencing a progressive transformation, with new teaching and learning practices appearing relatively frequently in connection with the successful integration of new technologies.

Narrative Material from Interviews

After reading the transcripts of the teacher interviews several times, we commenced coding and identified conflicts and tensions the subjects had to face at different stages of their struggle with modern technology in the classroom. The procedure for analyzing the material from the interviews consisted of the following two steps:

- Identifying the content of the conflicts and tensions expressed by teachers at various stages of their didactic design.

During this step, we analyzed the teachers' transcribed utterances collected after the recording of the lessons they conducted in the three semesters.

- Comparing the teachers' tensions and conflicts emerging at different stages of didactic design during the three semesters of the empirical research and referring them to the diagrams of the emergent teaching and learning practices.

This step led to the creation of a complete map of objective teaching and learning practices and the subjective meanings the teachers ascribed to these practices However, most importantly we traced the process of changes in practices and meanings over time. Therefore, we can say that the maps created document the school community's stages of learning. In other words, the maps show both the teacher's didactic practices that were observed and their changing discourse.

Findings: From a Toy to a New Educational Tool

This section presents the results of the video ethnography research in diagrams, or maps, of emergent teaching and learning practices in the classrooms during the three semesters of our analyses. The diagrams were created based on the coding that referred to seven categories, and they are complemented by the teacher discourse that expressed their conflicts and tensions regarding particular aspects of their work in the classroom after the subsequent cycles of research. As signals that accompany change, the conflicts and tensions are important elements of the analysis presented. In other words, we present the results of the interpretation of two analytical units for each semester of the research: the emergent teaching practices and teacher discourse.

We retained the time axis since it is significant for the emergent changes in the teaching practices in the tablet-mediated classroom. Each research cycle was provided with a title reflecting the gist of the problems that appeared in the classroom. These titles were drawn from the analysis of the interviews with the teachers and refer to categories that appeared most frequently during the teachers' discourse at given stages of the research.

The two subsections designated show two clear stages of changes in teacher didactic practice associated with the appearance of iPads in the classroom. They also document the progress made in teacher practices and in their understanding of the new tool and its educational functions. These are the stages that happened following the "wow effect" that refer to teacher expectations that the mere introduction of the iPads in the classroom would be "miraculous" (T2). Teacher progress can be defined as a gradual shift in teaching practice and understandings of the educational role of iPads from "magic wands" and "toys" to "tools" that can be used to realize the aims planned by the teachers.

Teachers’ Disappointment

For the majority of the teachers, the first semester of research in the classroom revealed that they experienced disappointment and the conviction that iPads “are a failure in the conditions of Polish schools” (T5). The teachers considered the investment in purchasing the iPads as not having been fully considered. We are convinced that the main problem evident in the first semester of the video ethnography analyses consisted of attempts to fit the new tool into the framework of existing practices and activities and subordinating it to them.

Figure 8.1 shows that teaching practices were almost entirely contained within the order of knowledge transmission. The collective table for this cycle of analyses shows that almost all of the teachers’ results ranged from 1 to 2.5 points. Only two teachers participating in the project exceeded the threshold determined as transmissive. Staying in this framework can be interpreted as a process that was independent of the teacher’s age and his/her personal attitude (positive or negative) to modern technologies.

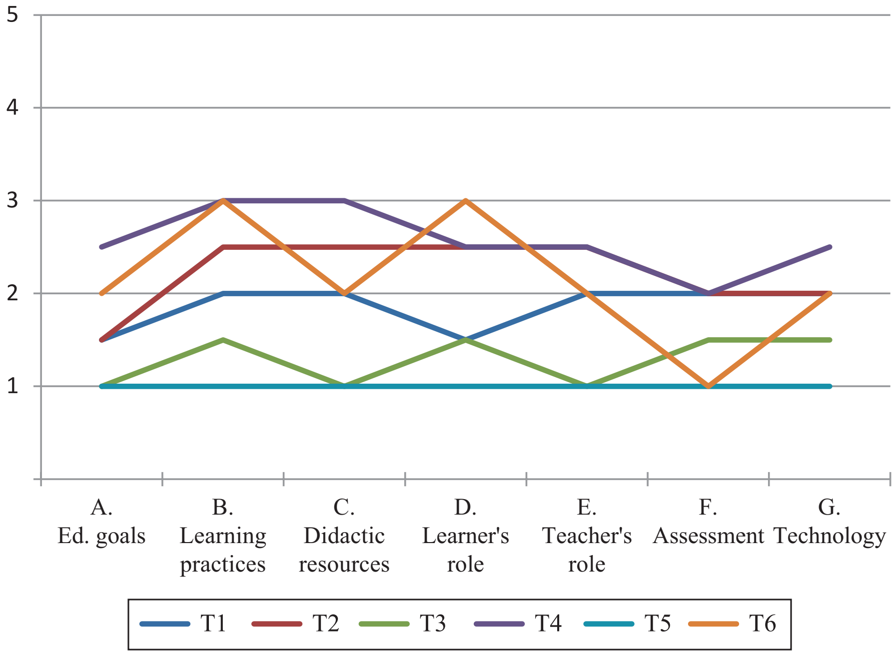

Fig. 8.1 Map of emergent teaching practices (semester I)
1.0–2.0 conservative teaching and learning practices
2.5–3.5 transition
4.0–5.0 progressive teaching and learning practices

A. *Type of educational goals adopted*: Most often these included the transmission and consolidation of knowledge or training specific skills. Educational goals were not always clearly determined by the teachers. They were most often related to the execution of the subsequent lesson topic, about which the learners were informed at the beginning of the lesson, while the range of skills and exercises to be done was not announced at all.
B. *Type of learning practices executed*: During the first semester, the learners used iPads most often to watch illustrative materials (excerpts of videos or presentations prepared by the teacher). In this sense, the learners' iPads were transformed into small, mobile TV sets, on which they could watch a video or a presentation at their desks (these presentations were also always shown on interactive whiteboards). During mathematics, English and religion classes, learning practices were more clearly connected with exercising and consolidating skills either individually or in groups (e.g., practicing addition and subtraction skills for a fixed period of time, followed by the comparison of results).
C. *Use of didactic resources*: The teachers considered textbooks and workbooks to be the leading resources of knowledge and skills. The applications selected by the teachers were strictly subordinated to the leading didactic materials (most often a single type of mathematical operations or a certain defined group of English vocabulary were practiced).
D. *Learner's role*: In their actions, the learners did not step beyond being passive recipients ready for knowledge prepared by textbook authors and their teachers. They played a more active role when practicing, when they were expected to perform efficiently, quickly, and correctly. The scope of their activity was dominated by actions related to memorizing and consolidating knowledge.
E. *Teacher's role*: During the first stage of our research, the teachers did not go beyond the role of experts transmitting knowledge or equipping learners with skills. The teachers had an additional task to perform, namely to organize activities during which iPads were used. This included distributing the devices to learners, controlling the time determined for the selected activity and ensuring that the learners did not use any other applications available on the devices.
F. *Assessment*: In this cycle of the analyses, assessment and feedback practices were presented sporadically as general summaries of the classes. It was often the case that the element of assessment and feedback for learners was entirely absent.
G. *Educational goals in connection with the role of technology*: It seems that the goals of the lessons analyzed could well be achieved without iPads since the devices were reduced to the role of a substitute screen for displaying video material. The tablets were used during very short, clearly limited time spans of up to 10 min. During this time, the learners had a chance to practice concrete skills such as addition, note-taking, or consolidation of English vocabulary. The use of technology did not move beyond a narrowly understood substitution and streamlining of the heretofore learning actions undertaken.

Analyses of the content of the interviews revealed some conflicts and tensions defined as primary contradictions that concerned the gist and sense of including tablets in the teaching process. All the participating teachers expressed such tension.

Fig. 8.2 Teachers’ discourse in the first semester

iPad	= toy		
	↓		
Learners:	fun	≠	Learning
	↑		
Teacher:	time consuming design		

First, they focused on the impossibility of fully subordinating technology to the textbook, which was the leading source of knowledge. The conflict was summarized in the question of whether tablets were toys or educational tools. The presence of tablets in the classroom was a great challenge for the teachers, and it was the source of serious doubt, which is why the teachers focused only on their own fears, anxieties and uncertainties regarding whether and how tablets might serve the aims of lessons. At this stage of the research, the teachers were essentially ready to discard the tablets as “toys” that were incompatible with the aims of the school. This tension was drawn from the interviews with the teachers in the first semester (Fig. 8.2).

This tension is illustrated by the following examples of teachers’ statements.

Teacher T1: I understand that now we need to teach in a more modern, more active manner and through play, but mathematics is one of the most serious subjects. Of course, I can use mathematical applications to consolidate simple operations but nothing more. A tablet cannot replace textbooks or workbooks.

An important conflict is also related to the time designated for the design of classes involving iPads. The teachers did not anticipate that this activity would take so much time, and additionally they found it hard to identify applications that were synchronized with the textbook.

Teacher T5: I must say I was very disappointed. There are so many applications, and I have no time to look through them. And there are no applications that fit the material from the science textbook for my class.

Teacher T4: In the case of English, I can see many possibilities for using iPads in the classroom. There are a huge number of applications, but the selection of the right applications and checking them takes much too much time. Recommendations on websites are not always reliable. Apart from this, I have to try out a given application myself before a lesson. I did not think that classes with iPads would be so demanding or that they would require so much time. It is true that such lessons are involving, but at what cost… at the cost of my time!

It is worth noting that the teachers’ conflicts and tensions clearly concern the teachers’ activity zone. Under this optic, the learner’s perspective is absent from the teachers’ discourse. The presence of tablets in the classroom was a great challenge for the teachers and a source of great doubt, which is why they focused only on their own fears, anxieties and uncertainties concerning whether and how tablets can be subordinated to the goals of lessons. At this stage of the research essentially the teachers expressed their willingness to discard the tablets as “toys” that were incompatible with the goals of the school.

Learner-Centric Progressive Teaching

The last cycle of research conducted in the third semester was, on the one hand, marked by efforts to deeply reconstruct teaching practices in connection with the appearance of technology in learning (with results above the 3.5 threshold), while, on the other hand, our research revealed that some teachers did not manage to reorganize their practices and continued obtaining results that fit the logic of knowledge transmission (i.e., below the 2.5 threshold) in the same period under analysis. The collective results are shown in Fig. 8.3.

A. *Type of educational goals adopted*: On the one hand, educational goals were not at all verbalized or were signaled unclearly, but the new teaching practices unambiguously included those covering clearly defined goals related to learner independence as creators of knowledge (results of 4 and above in category A).

B. *Type of learning practices executed*: Learning practices continued to include well-established individual exercises based on many fast repetitions (mathematical applications). The emergent new practices doubtless included group activities consisting of the independent, negotiation-based creation of knowledge by learn-

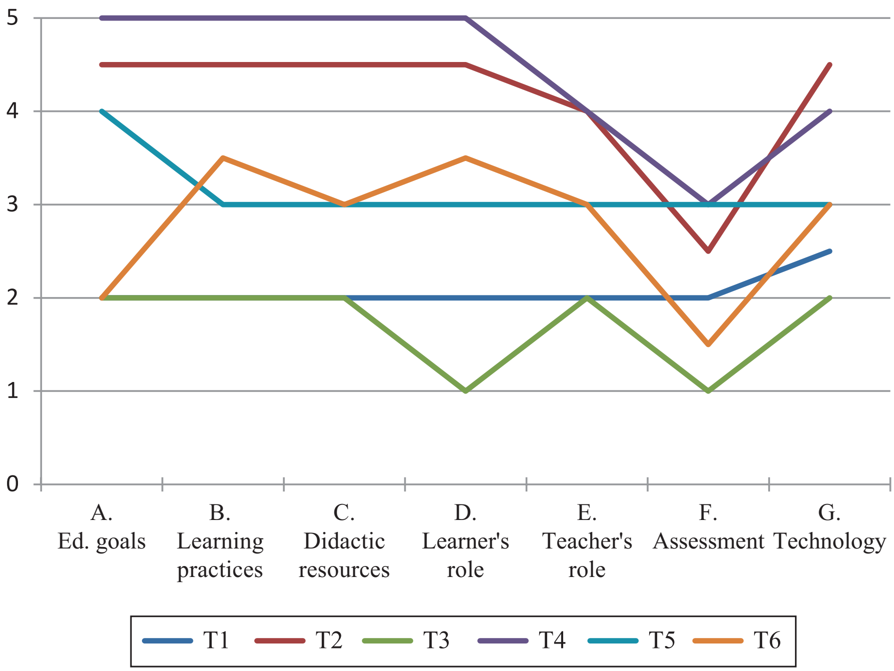

Fig. 8.3 Map of emergent teaching practices (semester III)
1.0–2.0 conservative teaching and learning practices
2.5–3.5 transition
4.0–5.0 progressive teaching and learning practices

ers from sources indicated by the teacher or from other sources. What was appreciated here was the learners' personal knowledge and experience.

C. *Use of didactic resources*: Strategies for using available resources were also very diverse. On the one hand, we noted the dominant role of the textbook, but there were also some clear attempts to break down this domination by balancing and multiplying sources. From the point of view of the process of the construction of knowledge by the learner in connective contexts, this emergent practice is of huge significance (results of 3 and above).

D. *Learner's role*: In this category both the traditional role of the learner as the recipient of ready knowledge (results below 2.5) and the emergent new framework of the learner roles were identified. The learners benefited from being causal agents in processing or creating knowledge. This reorganization of the learner role consisted in granting them a higher degree of independence and appreciating their technical competence, which resulted in the mandate for the creation of their own content.

E. *Teacher's role*: What was identified in this category was both a conservative tendency, which was the teachers' attachment to the role of the expert transmitting knowledge (results below 2.5), and efforts to change this role. By acknowledging the learners higher agency in the area of knowledge creation, the teachers "shifted" their own role towards that of consulting and mentoring practices, which facilitated the emergence of new teaching practices (results of 4 and above).

F. *Assessment*: Surprisingly, all the teachers obtained results that marked them as rather traditional (not more than 3), which meant that assessment and feedback practices were not a highly reconstructed aspect of their practices. Although there were single cases of evaluation in stages, assessments most often concerned the effects of work or the teachers limited themselves to a general summary of the classes. From the point of view of learners' independent construction of knowledge, this collection of teachers' practices raised concerns, since it left learners without adequate feedback on the quality of their work.

G. *Educational goals in connection with the role of technology*: In this category, we see both the use of technology in substitution and augmentation models (i.e., the frequently applied game-based approach such as the *Kahoot!* application that was used to check learner knowledge), but also clear attempts to modify learning practices through technology (designing books using *Book Creator* and designing presentations to explain natural phenomena with *Aurasma*). *iMovie* applications that combine narration, image, and sound were also used. Teachers also developed visual competences and algorithmic thinking through the practice of changing a tale into a game plot (*Bloxels* application) and other narrative games. Interactive books, which appeared during this cycle of our research (such as *WuWu* in English classes), were also used frequently.

At this stage of our research, the previously verbalized belief that iPads were not suitable for use during mathematics or IT lessons was also noted. This applied to teachers who did not perform any reconstruction in the area of their own teaching

Fig. 8.4 Teachers' discourse in the third semester

iPad = educational tool
↓
Learners: new forms of knowledge ≠ old educational aims
new skills

practices. However, other teachers at this stage of the reconstruction of their practices formulated conflicts and tensions clearly concerning contradictions between the reorganized activity and the neighboring systems of activity. This is illustrated by the following schematic diagram (Fig. 8.4).

Speaking in more detail, the teachers were concerned about how the new teaching and learning practices were going to meet the requirements of the education system when the learners changed schools in later stages of education. These conflicts and tensions concerned solely learner knowledge and its adequacy with regard to the requirements of the education system.

Teacher T4: The worst thing is that no one will ask them [the learners] whether they can design a game or make a video on *iMovie*. They will be assessed based on the results of tests, so we always need to keep a balance between their passions, involvement, new technologies, and the merciless tests, from which there is no escape.

Teacher T2: We attempted something we had not been aware of. Now, our school is upside down, we do everything in a different way and this greatly benefits the learners, who are no longer bored and who have begun to learn automatically. There is just one thing, the tests at the end of sixth grade. This could be a painful experience for the learners. No cooperation, no Internet, just a piece of paper and a pen.

The teachers who went the farthest in reconstructing and changing their teaching practices expressed teaching conflicts at this stage of the research concerning the incompatibility of new teaching and learning practices with the requirements of the traditional teaching system that their school was a part of. These are included in the following statement: the approach centers on learners as knowledge creators and the mere production of knowledge in situations with technological mediation reached beyond the materiality that is assumed in the Polish education system that is based on "pen and paper." The teachers were, therefore, aware that their practices had great transformational potential. However, this applied only to their particular school.

Discussion

Our analyses document two processes taking place in the school. We identified a slow shift from the logic of transmissive teaching to practices focused on learners and their learning. This was observed in emergent practices such as the organization of group-learning situations, the reorganization of knowledge, indicating alternative sources of information, using new strategies for assessing the creation of new reference frameworks of the learner's role and a more comprehensive use of technology. We identified the transfer process by analyzing the order in which the teachers expressed the conflicts and tensions. Initially, these included teacher work time and their involvement and the entertainment (and thus not educational) role of the iPads. Although the teacher's opinions of the iPads subsequently evolved to recognition of them as educational tools, the teachers still harbored concerns about the educational value of learner knowledge and their technically mediated skills from the perspective of education system requirements. We also perceived that the practices of assessing and providing feedback on learner projects, the reconstruction of which was the weakest aspect of the emergent practices, were somehow related to this "empty space" in the Polish system of education. Assessment and feedback on the effects of learning are more likely to be relegated to anonymous instances within the education system that is responsible for administering final testing than to the teachers who accompany learners daily in their learning.

The most significant conclusions resulting from our study concern:

- Change of the subjective meanings given to technology at the subsequent stages of our study by the teachers

Initially, the teachers perceived tablets as magic wands, then as toys having no educational potential, and finally as educational tools in their own right, which find their place in school materiality. However, it is impossible to determine whether the new meanings of technology are becoming a source of new practices, or whether the emerging new teaching and learning practices are becoming a source of new meanings of technology.

- Processual, slow emergence of new teaching and learning practices, finally accompanied by a deep reconstruction of the conservative pedagogy and the shift of the direction towards the pole of the progressive teaching practices

This shift applies to the following dimensions:

- From transmission of ready knowledge towards search for knowledge in group processes
- From an approach based on the "guessing" or "recollection" of the correct answer towards the process of joint exploration and discussion of various solutions
- From the transfer of certain, ready and constant knowledge towards uncertain, fragmentary, liquid knowledge
- From learning from the teacher's knowledge towards problem-based learning
- From memorization of information towards information processing
- From reproduction towards creativity and innovation

However, we cannot disregard the existence of teachers who made some other choices within the scope of their own practices and indicated an "incompatibility" between the tool and their subject area. The key to understanding the reserved attitude about the fuller use of iPads during mathematics and IT classes is the package of skills defined in the core curriculum for primary school for these subjects rather than the teachers' personal deficiencies or their decision to marginalize the use of tablets. In other words, we could not conclude that the teachers who did not reconstruct their own practices progressively did not understand technology. They understood the program requirements for their subjects, and these prevented them from a more intense use of tablets in teaching. Because of the core curriculum requirements, both the mathematics and IT teachers used the new tool marginally and rather infrequently; however, they did not verbalize this fact and only hinted in general at the "unsuitability" of iPads. Both the mathematics and IT teachers tried to integrate tablets in their classrooms but decided to step back to the pole of traditional (conservative) teaching practices. Their strategy was tantamount to a marginal use of tablets during classes, reducing them to a lesson attraction and their exceptional, infrequent use. The teachers concluded that tablets as a new tool do not guarantee the results required by the core curriculum for their subjects. For this reason, the risk of the establishment of new teaching and learning practices seems to be too high for them. Educational goals are reached in a safer way when traditional methods are used and when the emergence of new practices is limited.

Limitations

Our research was conducted at the request of the school administrators who indicated that their teachers were ready to participate in an engaging study and wanted to be provided with feedback on their practices. They consented to the presence of video cameras and the personnel who recorded their work. We know that some teachers at this school refused to conduct lessons with iPads, and they were necessarily excluded from the research. The presence of the cameras could also have caused some reservations among potential subjects since it was not only a convenient recording tool, but it was also a monitoring tool, which meant that knowledge regarding teaching practices could have been used variously including against teachers, and it could have led to the school director removing from teaching positions teachers who could not cope with technology in their teaching.

Our research was conducted on small samples; therefore, its explanatory power is limited. However, it is a study of educational change performed on a microscale, which we perceive as its main value. Nevertheless, it would definitely be worthwhile to extend the scale of the research to include larger groups of teachers and school teams to track areas in which the changeability of practices is related to the same domains of knowledge.

Conclusion

The aim of this chapter is to show how new teaching and learning practices emerged in a technology-enhanced classroom. We did not make any assumptions as to the manner in which this transfer might happen or as to what the change might apply to when an active element such as technology was introduced to the didactic design. Our study indicated that the great amount of diligent work that followed the "wow effect," which was a nonreflective expectation that the technology itself would produce educational effects without teacher involvement. We also present teacher disappointment with technology and of the technology for assisting teachers, as well as contexts in which technology made it possible for teachers to develop new pedagogical approaches and to further reconstruct their teaching and learning practices.

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Chapter 9
Material Conditions of Collaborative Knowledge Construction: The Case of Monoplant

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Abstract Monoplant is a prototype of an educational construction kit that provides teachers and secondary school students with hands-on experience on plant biology. We present the design rationale of Monoplant and report on its 3-week deployment in a high school classroom. The students ($N = 14$) used Monoplant to solve a photosynthesis assignment requiring them to compare the growth of two plants (one exposed to natural light and another to artificial green light). We used a qualitative approach to collect and analyze data, with observation, video recording, and interaction analysis as the main methods. The students worked in groups, and we video-recorded the verbal and nonverbal interactions of one group ($N = 4$). The two plants and Monoplant's visualizations of the plants' growth, together with the textbook, were the resources that the students used when solving the assignment. These material conditions provided an explorative design space for students' collaborative learning, and many hypotheses were raised during the hands-on activity with materials and representations. Furthermore, we suggest an emergent practice based on our findings, in which teachers, and not only students, need maker spaces for creating material conditions for students' domain-specific collaborative knowledge construction.

Keywords Collaborative inquiry · Collaborative knowledge construction · Curriculum-driven vs. self-driven learning · Design-based research · Empirical analysis · Material conditions · Monoplant · Photosynthesis · Participatory design · Physical context

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Introduction

With the advent of the Internet of Things, sensors have become available in many different forms and packages. Almost as flexible as Lego bricks, sensors are relatively inexpensive and can be used as building blocks in different applications. To explore this infrastructure for educational purposes, two of the authors designed and built Monoplant for teaching and learning plant biology. With Monoplant, plants in pots are connected to sensors that measure temperature, humidity, light level, and soil moisture. Monoplant supports students' hands-on interaction with plants and provides visualizations of the key environmental variables contributing to plant growth. With the design of Monoplant, the causal relationships of plant biology—that are important for understanding scientific concepts, such as photosynthesis—can be represented in meaningful ways. By interacting with Monoplant, students are stimulated to discuss, analyze, and reason with observed (biological) phenomena and (visual and numeric) representations to create alternative explanations, which is a step beyond learning *from* conventional textbooks (text and static diagrams) and rather learning *with* technologies (Jonassen & Reeves, 1996). Monoplant provides support of both physical and conceptual dimensions of learning.

The chapter is organized as follows. We argue that collaborative knowledge construction in computer-supported collaborative learning (CSCL) needs a material foundation that supports hands-on activities. We present the design rationale of Monoplant for addressing the challenge, as well as the research questions guiding our research. Then, our methods are described. Next, we present and analyze the data by showing concrete examples, and we discuss our findings by comparing them with those reported in related work. Finally, we present emergent practices based on our work of construction kits for teachers and teachers as designers.

Related Work and Theoretical Perspectives

We describe related work in the areas of material conditions for learning, tangible interfaces, and CSCL.

The material conditions of learning from a sociocultural perspective are associated with the tools used during learning and learners' use of spontaneous, everyday concepts before they can master scientific concepts (Vygotsky, 1978). A good teacher will make the students rise to higher levels by bringing their spontaneous concepts in contact with scientific concepts. As a result, the students will have the experience and related concepts necessary to construct scientific concepts. We argue that the use of Monoplant creates real-life experiences for students and triggers spontaneous concepts that become prerequisites for the scientific understanding of photosynthesis.

Säljö (2010) conducted early studies on the use of computer tools as mediating artifacts for teaching and learning practices. These tools do not only support learning but may also transform it. One role of computer tools in learning, according to Säljö, is to serve as a social memory: in addition to memorizing knowledge, we maintain a knowledge base connected with the tools we use (Säljö, 2010). Johri and Olds (2011) suggested the following three areas for future research on the social and material contexts for learning in engineering: (1) empirical studies on the role of representations, (2) empirical studies on mediation by the tools used in learning and practice, and (3) empirical studies on the differences between the use of representations and materials in learning. We address each of these in the study we report in this chapter. Marshall (2007) surveyed previous research on tangible interfaces to identify the benefits of technological artifact manipulation on learning. He found only a few studies that focused explicitly on the teaching and learning benefits of artifact manipulation and classified them into explorative activity and expressive activity. Both types apply in our case.

Within the past 10 years, technological innovations in society have created new opportunities for handheld technology in schools (Jahnke, 2015), and educational construction kits (a type of maker space) offer new ways of increasing engagement in learning through hands-on activities (Bdeir, 2009). Advocates say that these help motivate learning by encouraging active participation in science and technology topics (Resnick et al., 1998), and argue that physical interactions lead to a better learning transfer beyond classroom settings because of the improved grounding of students' learning in out-of-school experiences (Black, Segal, Vitale, & Fadjo, 2012).

By contrast, critics speak of hands-on activities being at odds with educational practice and increasing the tension between learner-centered (self-driven) and teacher-centered (curriculum driven) learning (Barricelli et al., 2016; Resnick, 1987). Self-driven learning is connected with constructivism and entails that a learner's prior experience must be the starting point for new learning activities and further guided by personal learning goals, but constructivist learning activities are time consuming in ordinary classrooms. Curriculum-driven learning starts from shared learning goals often defined nationwide for specific subjects to ensure that all students have a common core knowledge base. We attempt to strike a balance between self-driven and curriculum-driven learning with Monoplant by integrating students' hands-on activities with materials and representations and by giving students an assignment informed by the high school biology curriculum for grade 12.

Jimenez-Aleixandre, Rodriguez, and Duschl (2000) made a distinction between two types of classroom discourses—*doing science and doing the lesson*. Doing science is when students are talking science in the classroom (Lemke, 1990), and doing the lesson is when they are displaying the roles of students and the rules to follow when solving a task.

Collaborative knowledge construction is a pedagogical model that promotes talking science by raising questions or issues, followed by alternative answers (hypotheses, positions, or alternative explanations) and backed up by arguments either for or against a position on an issue (Ludvigsen & Mørch, 2010; Stahl, 2006). This learning model allows for the progression of scientific inquiry from a vague problem or poorly formulated question toward a clarification of the phenomenon being studied.

CSCL researchers have put technological manipulation and materiality in the background and foregrounded argumentative (discursive) learning processes, but studies have shown that active engagement with materials, representations, and artifacts can significantly enhance CSCL (Cerratto Pargman, Knutsson, & Karlström, 2015). Furthermore, teachers can use variations of collaborative knowledge construction for inductive learning methods, such as problem-based learning, discovery learning, and project-based learning (Prince & Felder, 2006). By putting materiality and representations in the foreground, researchers can begin to unravel the complex relationship between learning and technology inherent in sociocultural mediation (Cerratto Pargman et al., 2015).

The Monoplant System, Topic for the Observed Class

Two of the authors created Monoplant from basic hardware and software components as a part of their Master's thesis (Seibt & Kjelling, 2014), and it took about 2 years to design and build it. The hardware consists of five sensors that measure, record, and store data variations in the plant's growth environment, an Arduino prototyping platform connecting the low-level electronic sensors to higher-level electronics (Arduino, 2017), and a Raspberry Pi programmable computer (Raspberry, 2017). The hardware system (Fig. 9.1) consists of a wireless network adapter, a high-definition webcam, a powered USB hub, and the Arduino to the Raspberry Pi (2012 model). Arduino and Raspberry were chosen because they are open source

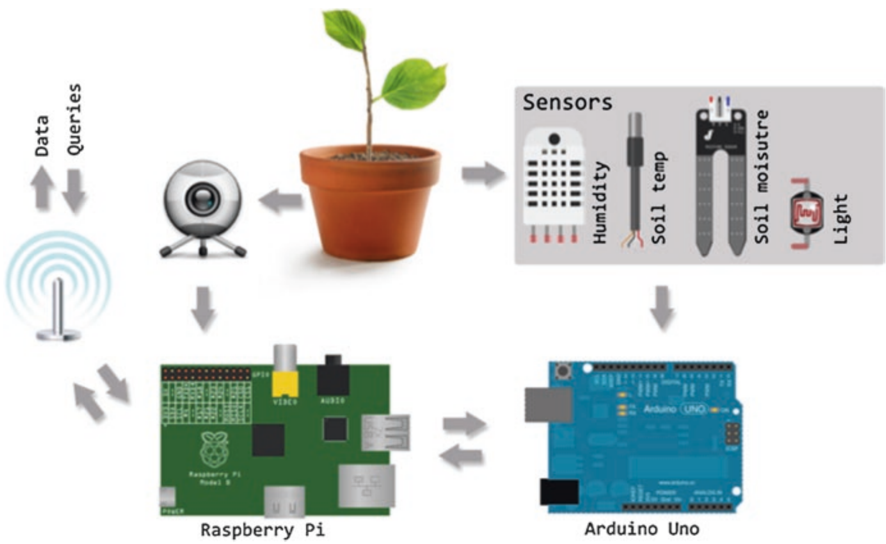

Fig. 9.1 High-level illustration of the hardware components in the application

hardware and software platforms and provide for flexibility in adaptation. Monoplant has not been commercialized and remains a prototype. Teachers were not involved in the technological design, but a teacher was involved in the pedagogical design we describe in the Methods section (Murad, Mørch, Herstad, Seibt, & Kjelling, 2015).

The data collected by the sensors are posted to an application programmer's interface (API) and stored in a common repository (cloud). The API provides an interface between the data collector and the user interface. The software consists of an architectural style for distributed hypermedia systems (Fielding, 2000). It uses Ruby on Rails, an open-source web application framework with the Ruby object-oriented programming language. Furthermore, time-lapse video software, which enables observing the details and nuances of a growing plant because time-lapse photography utilizes snapshots taken at fixed intervals, as well as HTML5 and JavaScript, is used to display the data collected by Monoplant.

Each day at midnight, the system collects all the images taken during the day and combines them into a time-lapse video played back at 30 frames per second. As the Raspberry Pi captures approximately one picture per minute, 2 s in the video equals 1 h in real life, and 1 day is represented by a time-lapse video of 48 s. Thus, after 24 h of data collection and storage, videos in different formats are generated, and Monoplant is ready to display information to users (Seibt & Kjelling, 2014).

The main web page of each plant represents the current state of the plant (Fig. 9.2). The pane on the upper left side of Fig. 9.2 displays the last picture with the corresponding values for temperature, humidity, light, and soil moisture. The large pane on the upper right side shows a time-lapse video from the day before, with a corresponding graph showing all the sensor values throughout that day.

Photosynthesis is the biological process and scientific concept that was the topic for teaching in the class we observed (Sletbakk et al., 2008). It is the process by which green plants use chlorophyll in their leaves to transform energy from light to chemical energy, often in the form of glucose, which is used by the plant to build seeds, leaves, and flowers. Oxygen is produced as a by-product of the plant biochemical process, and it enables humans and all other animals to breathe. Photosynthesis occurs more in blue and red light rays than in green light rays (Nishio, 2000).

The overall aim was to provide an understanding of students' manipulation of physical materials and representational artifacts in Monoplant, while collaborating in small groups to learn about photosynthesis with some guidance from two facilitators. The following two research questions were explored:

1. What material conditions of collaborative knowledge construction does Monoplant bring to the foreground?
2. How does Monoplant, by presenting photosynthesis differently from established educational practices, reflect tensions between curriculum- and self-driven learning?

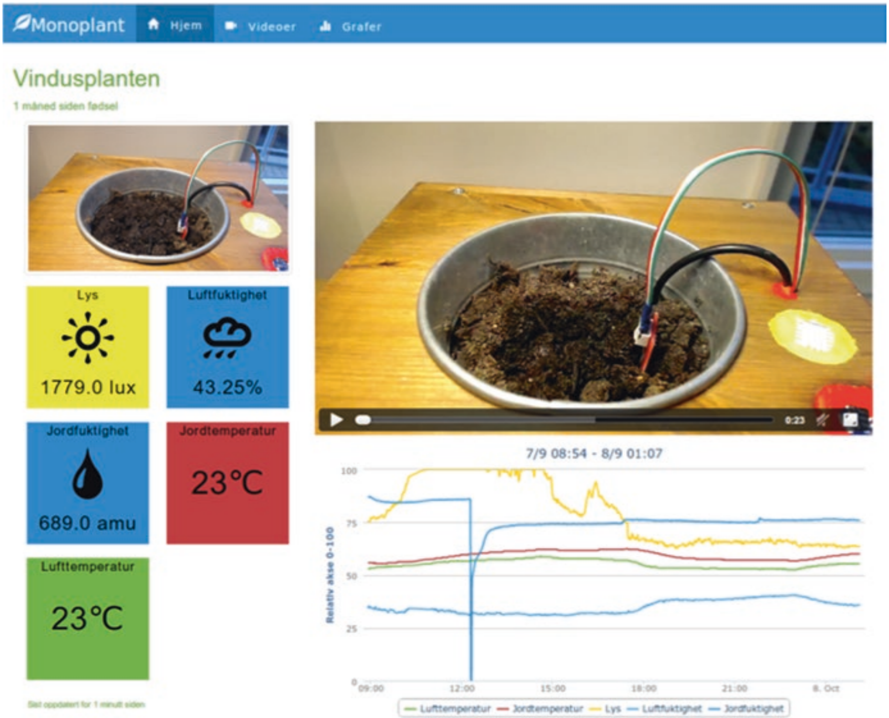

Fig. 9.2 Monoplant's user interface displays the values of the plant's physical variables and growth behavior by static and dynamic visualizations (snapshot, current attributes, video, and graph)

Methods

Data collection took place in an upper secondary school in Oslo. We contacted the school half a year before the trial and asked if a biology teacher would be willing to use Monoplant in one of his classes instead of performing the textbook experiment about photosynthesis (Murad et al., 2015). Our interventionist approach combines participatory design (Simonsen & Robertson, 2013) and design-based research (Hoadley, 2002), in which a teacher and two researchers collaborated to design and deploy an innovation while conducting an experimental study of the innovation. The biology class consisted of 11 girls and three boys ($N = 14$) aged 17–18 years (on their last year in high school).

We used qualitative methods for data collection, classification, and analysis. First, we observed and video-recorded spoken interactions intertwined with physical actions by four of the students. Second, data classification used thematic analysis and was informed by research questions, argumentation models (Ludvigsen & Mørch, 2010; Stahl, 2006), and the student assignment questions created by the teachers. Third, interaction analysis (Jordan & Henderson, 1995) was used as our

Table 9.1 Transcript notation for conversational data

Notation	Indicating
[..]	Excluded speech from person speaking
((*text*))	Comments/explanation by researcher
text.…	Speech fading out
[text]	Talk on top of each other
(..)	Short pause in talk 0–0.5 s
(.number)	Short pause in talk, time of pause in s.
::	Abruption of talk
courier	Written (e.g. GUI) text read out loud
{{*move n*}}	Physical action/movement by person

main method for analysis. Interaction analysis is a method for the empirical investigation of human activities, such as talk, nonverbal interaction, and the use of artifacts and technologies (Jordan & Henderson, 1995). The transcript notation is shown in Table 9.1.

Experimental Setup

After a demonstration of the system to the teacher, followed by a discussion of its functionality, the teacher suggested that we conduct two experiments using the different sensors in the system to control the change in one variable while keeping the others relatively stable. We agreed that the factors that would be easiest to control are light intensity and light quality (wavelength). The first experiment would involve keeping the plant located in a window facing west, receiving sunlight and light from fluorescent indoor lighting. In the second experiment, the plant would be relocated to a lightproof cabinet where it would only receive light of a known wavelength, and it would be compared with another plant located in the window (Fig. 9.3).

The students had access to Monoplant for 3 weeks and used it for preparatory work. When the assignment was handed out, the students were seated in groups and were asked to collaborate. We reported on a 45-min session of one group of four students and go into the depth of their conversation during the first 17.5 min. The assignment consisted of five questions about photosynthesis covered in class and adapted to the unique setting, which included comparing two conditions for exposing plants to light (Fig. 9.3).

Results

The plants in the cabinet grew more than the plants exposed to sunlight, which, on the basis of first impression, is contrary to common sense. The experimental setup encouraged the students to question their previous (textbook) understanding of a

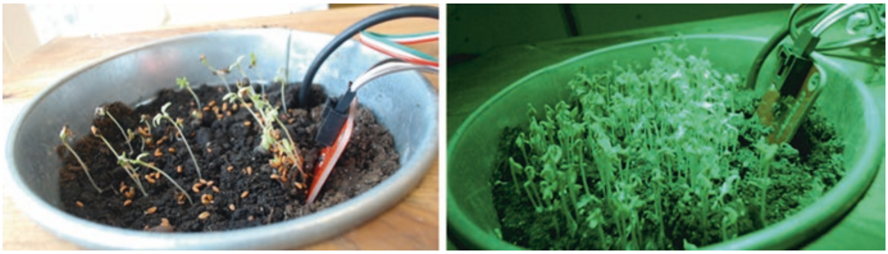

Fig. 9.3 Left: plant A receiving natural light in the window; right: plant B receiving green light in the cabinet

Table 9.2 Number of utterances and hypotheses generated by the students

No./student	Linda	Nora	Siri	Fredrik	All
Utterances	14	118	182	67	381
Hypotheses	0	3	8	4	15

scientific process, develop new knowledge, and integrate their skills into a real-life context. Table 9.2 shows the number of utterances and hypotheses (personal explanations, tentative answers) generated by the observed group and captured on video. The names of students are fictitious, and Siri is a person and not a virtual assistant.

Monoplant mediated the students' actions but not their conversations, which were mediated by the assignment, group organization, and the teacher's scaffolding. During thematic coding, we identified the following types of utterances: (1) asking questions, (2) proposing hypotheses, and (3) arguing for and against the different hypotheses by (3a) referring to observations and (3b) pages in the textbook. We identified 15 hypotheses proposed by the four students during the 45-min session. The hypotheses were named and chosen by the authors and assessed to be representative of the data. During hypothesis generation and argumentation, the students made frequent references not only to visual representations obtained from Monoplant, such as graphs and time-lapse videos (see Fig. 9.2), but also to the actual plants (see Fig. 9.3) and the textbook (Sletbakk et al., 2008). These actions and interactions were the focus for our analysis.

We present the results along four student hypotheses: green light, stem color of the plant, energy source in the seed, and delayed leaf budding. Each subsection starts with a brief context description, followed by the excerpt in verbatim transcription, and then our analysis.

Student Hypothesis 1: Green Light

The students were divided into groups of four. The group we followed has read the assignment and noticed the differences of the two conditions. Siri, one of the four students, read the first question aloud: "What did you expect would happen?" The students have rehearsed some of the theories presented in class (e.g., soil moisture decreasing over time). The students appeared slightly nervous at first, but as we proceeded, they became more relaxed and motivated, and the discussion shifted from making general observations to generating personal explanations, as shown below:

Time	Who	Utterance
2:16	Siri	… It was when the plant was put in {{*points to cabinet*}} the cabinet; it should have been exposed only to green light … but it is possible, for example, that a small amount of other light could have entered the cabinet, as well … so it's not for sure that the plant was exposed only to green light …
2:31	Nora	{{*Nods*}}

Siri promptly started with a conjecture about the plant in the cabinet (plant B). She proposed that the plant received more green light, indicating that there could be an error in the experiment. Nora agreed with this by slightly nodding. Siri implied that the plant in the cabinet would not grow as tall as plant A in the window.

The student textbook (Sletbakk et al., 2008) contained a graphical model of photosynthesis that showed how solar energy is used to excite electrons in chlorophyll molecules, but the students were not able to connect the model with plant B's growth pattern. The book also contained a graph of different pigments according to the wavelengths of light they absorb, clearly showing that chlorophyll absorbs little green light. The teacher used this as a discussion point in earlier lectures; he asked why the plants' leaves appear green.

Student Hypothesis 2: Stem Color of the Plant

The group, as a whole, did not share the hypothesis of Siri supported by Nora, but it was not discarded. The students started to search for alternative explanations, which was triggered by a surprise observation of Siri:

Time	Who	Utterance
2:47	Siri	Or almost all green light at best … {{*pointing toward the desk*}}, but how much did it actually grow? Is it that one {{*pointing to plant B sitting on the desk*}} that was previously in the cabinet?
2:52	Sjur	Yes!
2:53	Nora	Wow(!) ((*Becomes surprised to learn that plant B has grown more than plant A*))
2:53	Siri	It has grown a lot ((*smiles*)).
2:59	Siri	But were the stems of the {{*points to the window*}} plant in the window also white? ((*Referring to the observation on plant B's white stem color*)).

Siri was surprised to find plant B being taller and more plentiful than plant A. The first hypothesis had now been contested by one contradictory observation and a new hypothesis: (1) plant B grew more than plant A, and (2) plant B has a white stem color.

The second observation led Siri to asking, "But were the stems of the plant in the window also white?" This question was useful because a plant that does not absolutely undergo photosynthesis would most likely be white, as a result of having no pigments. The reason she asked this might be related to a comment made by a classmate in a previous lecture that when plants were placed in the basement for winter storage, their leaves would turn white.

Student Hypothesis 3: Energy Source in the Seed

The teacher joined the group 11 min later and asked the students to explain why plant B grew more than plant A. Siri repeated her green light hypothesis (Hypothesis 1). At this point, they enter the following conversation:

Time	Who	Utterance
13:44	Teacher	Yeah … so you think that … the relationship between growth and photosynthesis is clear to you … you can't imagine that a seed can sprout and grow without undergoing photosynthesis?
14:00	Fredrik	There are some plants that do not undergo photosynthesis … but they still grow, don't they …? There must be a small energy pack inside the seed? Isn't that so?
14:14	Teacher	Okay, is it?
14:14	Nora	Yes {{*nods*}} ((*agreeing*)).

The teacher raised a question that challenged Siri's first hypothesis, making the group to think that light is not the only source of growth. By using the words "seed" and "sprout," the teacher did hint at germination (Sletbakk et al., 2008). Fredrik proposed the hypothesis that some plants grow without photosynthesis and use an "energy pack inside the seed." The teacher asks them to elaborate. Nora agreed with this, but at that point in the conversation it was not clear if this was the shared understanding in the group.

Student Hypothesis 4: Delayed Leaf Budding

The teacher left the group. One of the researchers asked the students to watch the videos of each of the conditions to see if any discrepancy exists in the sequence of leaf appearance in the two plants. The students observed plant B and found that it is mainly the stem that grows, not the leaves. Fredrik requested that they also check plant A for comparison, and Siri started the video from October 29 showing plant A's growth process. The following conversation takes place:

Time	Who	Utterance
17:12	Siri	See, the leaves open up almost immediately {{*Nora looks at the video of plant A ((and compares it)) with plant B that was put on the desk*}}.
17:15	Fredrik	Yes … ((*silence, waiting for the video to finish*)); it could be that it needs the leaves {{*places one hand over the desk, then moves it quickly up in the air, as if trying to capture something falling in the air*}} to capture light, but {{*nods toward the cabinet*}} it doesn't really need this function when growing inside a cabinet … hmm perhaps!
17:34	Siri	… it uses more of the nutrients in the soil and the seed when growing inside the cabinet?
17:37	Fredrik	Hmm … yes. Or alternatively … it doesn't use the sun … or the light in the cabinet, and, therefore, doesn't need its leaves to pop up early … or yeah {{*gesturing with his hands simulating the growing plant that receives sunlight through its leaves*}}.

Siri mentioned that the leaves of plant A open almost immediately. Fredrik agreed, waited for the video to pause, and then said that plant A used its leaves to capture light, whereas plant B does not need this function. Siri clarified in a questioning tone if Fredrik meant that plant B compensates by using more nutrients from the soil and the seed to grow. Fredrik agreed somewhat hesitantly but suggested an alternative (delayed leaf budding) hypothesis that plant B's leaves pop out late because there was no sunlight to capture. Siri and Fredrik were both partly right but were unwilling to agree on the same hypothesis or to synthesize their hypotheses into a common understanding. Perhaps, they still wanted to hold on to their own hypothesis until further evidence would confirm or refute it.

The textbook explanation of the phenomenon is that photosynthesis occurs in the leaves. Different pigments in the chlorophyll can absorb photons, which can excite electrons and then trigger other photosynthesis subprocesses. Plants, therefore, need leaves to perform photosynthesis. However, the book does not say anything about growth without photosynthesis, such as in locations of little light and for white-colored plants, the scenario that the students are faced with in this experiment. Thus, the students were discussing a complex phenomenon that was not fully explained in the textbook and that required them to use their own vocabulary and propose alternative hypotheses obtained from multiple sources, their teacher's feedback, and unsatisfactory previous hypotheses. However, the group was not able to converge on a common solution.

We show in the next section that by stimulating interactions with materials and representations, in addition to verbal interactions in the group, the Monoplant system can provide a rich set of material conditions for collaborative learning that promotes the exploration of alternatives. Following others (e.g., Cerratto Pargman et al., 2015), we argue that such a broad, physical–conceptual, learning environment is necessary for a deeper understanding of the complex relationship of science learning and technology mediation.

Discussion

We summarize our findings by discussing our research questions raised in the beginning of the chapter and comparing our results with some of the results and recommendations reported in the literature surveyed.

What Material Conditions of Collaborative Knowledge Construction Does Monoplant Bring to the Foreground?

Monoplant gives students access to two types of materials: physical materials (plants, pots, etc.) and visual representations (videos, images, graphs). The students engaged with all of the materials but to varying degrees, and some students were more active than others. Our study provides an example of empirical research on mediation by physical tools used in science learning and combining representations and materials during the learning process (Johri & Olds, 2011). However, our data do not allow us to differentiate the relative importance of physical materials, textbook illustrations, and computational representations on collaborative learning, because we did not distinguish the different types of materials in the experimental setup. This shortcoming indicates an area for further research.

The students used materials in both explorative and expressive learning activities (Marshall, 2007). They were exploring alternative answers (generating hypotheses) when solving the assignment, and the multiple representations and interactions with the plants aided exploration. The students were expressing personal learning goals by choosing to interact with a certain representation, thus revealing interest and favoring a specific hypothesis, which, perhaps, can be connected with personal experiences and prior knowledge (e.g. that plants placed in basement for winter storage would end up with white leaves). However, this behavior cannot be determined with certainty on the basis of our research methods, and it was partly prompted by the teacher and the two research assistants, as they occasionally interacted with the students to scaffold the learning activity.

We found preliminary evidence of multiple levels of interaction with materials and representations when student proposed a new hypothesis:

1. Students would choose among different representations, such as a static picture, a textbook diagram, a video snippet, and visible plant properties, among others, when proposing a new hypothesis;
2. When two hypotheses by students were proposed, they were compared, contested, and (if not rejected) integrated to form a better one (this did not occur during the first 17.5 min, but occurred later in the 45-min session; for instance, Siri and Fredrik proposed competing hypotheses that were each partly correct and were eventually combined); and

3. If a student hypothesis was found to be incompatible with later observation and scrutiny, it would be replaced with a better one (e.g., Siri's green light hypothesis was later replaced with a stronger one by Fredrik and supported by Siri, as she gradually adopted a scientific attitude).

These three levels of interacting with materials and representations during collaborative learning with Monoplant are tentative findings and require further investigation.

How Does Monoplant, by Presenting Photosynthesis Differently from Established Educational Practices, Reflect Tensions Between Curriculum- and Self-Driven Learning?

The tension between self-directed and curriculum-driven learning is manifest in several respects. Self-directed learning means that students pursue individual trajectories (based on prior knowledge and experiences) using preferred methods and directed toward personal learning goals (e.g., different interpretations of assignment) and is exemplified by Fredrik and Siri proposing and arguing for different hypotheses.

However, during our observations, the students were evidently interested mostly in learning the curriculum and in memorizing correct answers to the assignment questions anticipated to be in an upcoming test and in the final exam. The students therefore seemed focused on what was expected of them based on established educational practices. In other words, they were primarily interested in "doing school" (Jimenez-Aleixandre et al., 2000).

By engaging in collaborative knowledge construction while interacting with Monoplant, the students were doing science (Jimenez-Aleixandre et al., 2000) but were doing so by using everyday language to explain what is happening. The students' talk during their scientific inquiry could have been lifted a notch by the teacher if he reminded them more often to use scientific concepts in explaining the observed data, thus integrating the hands-on activity with the desired student behavior. For example, when the teacher interacted with the students in hypothesis 3, they were prompted to reflect on how the plant can grow without photosynthesis, but he did not lead them to using scientific concepts to more accurately verbalize their understanding.

In other words, the students are capable of navigating both types of representations separately and can manage multiple representations of the same kind (for example, in hypothesis 4, the students discuss content from a video while pointing to one of the plants), but they are not able to connect representations across the two domains. Therefore, we did not find evidence of the direct application of scientific concepts when the students were left to discuss on their own. It only occurred when the teacher triggered the students to use scientific concepts. The students seem to suppress their curiosity when doing schoolwork and not referencing scientific models when doing science with Monoplant.

Some changes in institutional practice might be necessary before the students' experiences created with Monoplant and related educational maker spaces can function as anchors for learning scientific concepts in school, perhaps along the lines suggested by Vygotsky with the notion of using spontaneous concepts as building blocks of scientific concepts (Vygotsky, 1978). This hypothesis is currently a tentative one based on our findings. Further research is needed to determine what kinds of institutional practices should be introduced to high school students in our case. We suggest one approach in the final section.

Conclusion and Directions for Further Work

The overall aim of the study reported in this chapter was to understand students' hands-on activity with physical materials and representational artifacts of Monoplant while collaborating in small groups to solve an assignment on photosynthesis. Two of the authors designed and developed Monoplant from basic hardware and software components (Seibt & Kjelling, 2014). It consists of a biological plant with five sensors attached, a cloud solution for storing data, and a user interface on a web page that displays a range of dynamic and static visualizations of a plant's growth process.

Monoplant was deployed in a high school classroom for 3 weeks. The students interacted with Monoplant to solve an assignment in groups of four. We used a qualitative approach to collect and analyze data, with observation, video recording, and interaction analysis as the main methods. We video-recorded all spoken utterances and turn taking in one of the groups, with a focus on the students' conversations interspersed with physical actions toward the plants, Monoplant, and the textbook to access information for help in answering the assignment.

The students proposed and discussed alternative answers to the assignment questions based on the different materials and the representation they had access to. The learning environment thus promoted both self-directed learning through personal learning trajectories (by following a chosen hypothesis toward a conclusion) and curriculum-driven learning through the assignment that was created together with the teacher.

We also found that the textbook's and the teacher's presentation of photosynthesis provided students with scientific vocabulary, and Monoplant provided them real-life (physical) experiences related to the assignment. The students had difficulty connecting the two forms of representations (textbook/lectures and Monoplant/plants), and the teacher became central for scaffolding by enabling the students to move from concrete experiences with Monoplant (spontaneous concepts in our transcripts) to the more abstract language used in the textbook (scientific concepts). But this was realized only in a few instances, as the teacher also attended to other groups. Directions for further work include but are not limited to the following:

- The basic building blocks of Monoplant (go back to Fig. 9.1) offer a maker space for two researchers to create Monoplant. Now, imagine a meta-design environment for teachers to accomplish the same using end-user development (e.g., Fischer, 2009; Mørch, Hartley, Ludlow, Caruso, & Thomassen, 2014). What should be the level of abstraction of its building blocks? Should it be low level and general (like we used for building Monoplant) and enable a wide range of learning environments in science and technology topics, or should it be high level and domain specific, which is easier to use for non-techies but with a narrower range of application?
- We propose the comparison of the relative strengths and weaknesses of different types of materials (biological and physical) and representations (digital and textual) to complement collaborative learning as a verbal activity.
- We also propose to further investigate the three levels of interactions with materials and representations during collaborative learning with Monoplant, which are tentative and require additional research for harnessing, including reusing, refuting, and adapting the three levels.

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Chapter 10
Orchestrating Learning as an Emergent Practice in the Use of Location-Based Games with Mobile Devices

Jimmy Jaldemark, Sofia Eriksson Bergström, and Peter Mozelius

Abstract This study discusses the inclusion of location-based games and mobile devices in an educational setting that embraces both indoor and outdoor sessions. The study was built on a framework including learning as a social and collaborative phenomenon. Two case units, in terms of a fifth grade Social Science class and a sixth grade Mathematics class, were included in the study. Each case unit embraced an indoor preparing session, an outdoor session including mobile devices and the location-based game Pokémon GO, and an indoor follow-up session. The chapter aims at contributing to the understanding of how students and teachers together, in an emergent practice of orchestrating learning, apply mobile devices and location-based games in their educational setting. From this aim, the following research question unfolds: How could location-based games and mobile devices be applied by students and teachers to orchestrate learning in middle school settings? Data were gathered by semi-structured group interviews and video recordings with 20 students and two teachers. Moreover, documents such as lesson plans were included in the dataset. In the study, it was found that students and teachers participated in a shared and emerging practice of orchestrating learning and teaching. In this practice students and teachers acted as co-designers to orchestrate the application of location-based games and mobile devices in the educational setting. Findings suggest that an orchestration including a combination of a collaborative approach to learning, location-based games and activities that embrace outdoor and indoor sessions has the potential to vitalize and enhance traditional classroom-based education. However, there is not a guarantee that all students will concentrate on the given task, and just as in an ordinary classroom setting, teaching and learning also require careful orchestration.

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Introduction

Digital game-based learning builds on the older concept of game-based learning, wherein strategy games such as Chess and Kalaha/Mancala have been used in educational settings for thousands of years (Barnes, 1975; Murray, 2015). However, the concept of digital game-based learning is an emerging field for researchers as well as teachers in the twenty-first century (Hamari et al., 2016; Van Eck, 2006). Researchers are interested in utilizing the game-based approach and studying its effects on teaching and learning (Vlachopoulos & Makri, 2017). Teachers have a more "natural" opportunity for implementing this approach because education embraces childhood play, which is more evident in kindergarten than in the subsequent years of schooling. The study presented in this chapter discusses digital games as a subfield within the wider field of game-based learning. In the study, this approach to enhance learning through mobile devices was integrated into the curricula of the studied middle school.

The recent discourse regarding digital games in education could benefit on the fact that play-based learning and "walking sessions" were frequently used approaches in ancient Greece. The most well known are the peripatetic teaching and learning sessions led by Plato and Aristotle, which were held in the Lyceum of Athens. The term "peripatetic" can be defined as "walking about place to place, traveling on foot" (Pocock, 2002, p. 1). This is a concept that is still used in academic settings. As argued by Carreiro (2005), walking has the potential to stimulate discussions and collaboration. Utilizing walking and building on the potential of play and games in learning, this chapter discusses a gamified application that was designed and applied in a middle school educational setting in Sweden. Therefore, this study presents and discusses experiences and takeaways from the orchestration of learning in a middle school setting.

The study discussed in this chapter was born of an interest in what happens during the interplay between human beings, their surroundings, and mobile technologies in educational settings. This interest builds on how children's motivation to learn could be enhanced by educational design. Therefore, this chapter focuses on the orchestration of learning in middle school settings. The chapter aims at contributing to the understanding of how students and teachers together, in an emergent practice of orchestrating learning, apply mobile devices and location-based games in their educational setting. From this aim, the following research question unfolds: How could location-based games and mobile devices be applied by students and teachers to orchestrate learning in middle school settings? The chapter includes different design concepts applied in the orchestration, methods to record and analyze the orchestration, the application of location-based games and mobile devices to orchestrate learning and, finally, some lessons learned and conclusions derived from the study.

Background: Theoretical Lens

The subsections below deal with theoretical concepts of the study. The first is a discussion of the distinction between play and game, which is seen as a departure point for discussing teaching, learning, and issues of orchestrating digital game-based learning.

Distinction Between Play and Game

During recent decades, childhood sociology has changed to view children as active and participatory in shaping and changing the reproduction of their own childhood (Corsaro, 2011). With the development of childhood as a social structural period, the research of the child and childhood also developed (Qvortrup, Corsaro, & Honig, 2009). James (Qvortrup et al., 2009) points out that the origin of the understanding of the agency of children can be traced back to the 1970s. Up until then, the view of childhood as a preparatory period for adulthood had been unchanged, and children were seen as dependent receivers of the actions of adults. The new paradigm embraces children as social actors who create and are created by the circumstances they encounter. In this dynamic field of reproduction and production, children interpret adult culture as well as make it their own, and the creation of peer cultures has become fundamental. Peer cultures, which can be understood as a form of collective agency, are defined as a set of activities or routines, artifacts, and values which children produce and create together. A peer culture embraces creativity and imagination as important foundational ideas that inform the actions that create such cultures.

Through this lens of student creation, play is a central phenomenon (Corsaro, 2011). Play should be seen as a free and non-serious activity. According to the Dutch historian and cultural theorist Huizinga (1955/1938), play is a "prime mover" for humans in general. Huizinga's description of man as a Homo Ludens, naturally playful beings with play as a fundamental condition for cultural activities, could be traced back to Friedrich Schiller's romantic idea on play drive (Spieltrieb). Play drive is a concept in which a person is seen as fully human only when playing (Schiller, 1982/1794). It should also be emphasized that play differs from game. A game has been defined as "a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome" (Salen & Zimmerman, 2004, p. 80). Looking at play and games as essentially different phenomena, there must also be a distinction between playing and gaming (Rodriguez, 2006). Because of this distinction, the study approached design and digital games in schools from a different angle. The walking sessions are described as game-based activities, even if the interplay between students involved both gaming and playing. For further information regarding the design of walking sessions, see the study section below.

Digital Game-Based Learning

The concept of digital game-based learning (DGBL) grew in the 1980s when Malone (1981) analyzed why digital games are strongly engaging and motivating. Malone's main findings consisted of three key components: challenge, curiosity, and fantasy. Another DGBL pioneer studying how games might stimulate motivation and support was Lepper. Built on common findings, Malone and Lepper together created the Taxonomy of Intrinsic Motivation. In a two-level taxonomy, the concept of intrinsic motivation is divided into the levels of internal motivation and interpersonal motivation (Malone & Lepper, 1987). Both these levels of motivation were built into the orchestration of learning in this study.

Linked to the development of DGBL in the twenty-first century is the emergence of mobile gaming and learning enhanced by mobile technologies (Hamari et al., 2016; Huizenga, Admiraal, Akkerman, & Dam, 2009). In earlier research, digital games have often been associated with a sedentary lifestyle, and it has been highlighted that children risk developing obesity by gaming extensively (Tremblay & Willms, 2003). Nevertheless, motivational aspects of learning supported the idea of adding mobile gaming as a design element built into the orchestration of learning.

In addition, the last year's research on DGBL has branched out to also include the so-called exergames, defined as games that are designed to encourage physical activities such as walking (Huang, Wong, Lu, Huang, & Teng, 2017). Besides enhancing motivation, walking is included in the orchestration of the current study to support outdoor educational activities.

A branch of DGBL that particularly relates to walking is location-based games (LBGs), a category including exergames such as Zombie Run (Laine & Sedano, 2015), and tailor-made educational games like Frequency 1550 (Huizenga et al., 2009). The most well-known location-based game by far is Pokémon GO, a game that has been studied both as an exergame (Wong, 2017) and as an augmented reality game (Serino, Cordrey, McLaughlin, & Milanaik, 2016). The game is location-based and was built to augment reality with the support of smartphones and tablets. Such LBGs are classified as a subgenre of pervasive games since they expand the spatial, temporal, and social boundaries of traditional games. Furthermore, the locations of players, avatars, tokens, or other game objects in LBGs to various degrees determine the game's dynamics. A mobile LBG uses the GPS satellite positioning system of devices to map game features to real-world locations. The LBG genre consists of exergames with physical exercises as the main feature (Laine & Sedano, 2015), but also of games that can be used for other educational purposes. LBGs can also be a combination of these two in the so-called educational action games, and involve intense physical activity and clear learning objectives (Avouris & Yiannoutsou, 2012). The application of an LBG in the study allowed the orchestration of learning to reach beyond the classroom and bridge indoor and outdoor features of the educational setting.

Pokémon GO is not the first LBG, but the game is the first global success in the genre (Colley et al., 2017), as more than 100 million users from 30 countries downloaded the game within a few weeks after its release in June 2016 (Zsila et al., 2018). There is, so far, no explanation for the game's blockbuster success, but a study by Zsila et al. (2018) identified three game-specific motivational factors: outdoor activity, nostalgia, and boredom. The game is a mix of realism with real-world maps depicting roads, buildings, and lakes correctly, and a fantasy world with Pokémon figures originating from a Japanese card collection game. In the digital LBG version, a collection of virtual monster figures pop up on mobile screens and can be captured by players with the use of virtual balls (Fig. 10.1).

To reach higher levels, players need to visit real-world locations (Fig. 10.2), capture as many virtual monsters as possible and to earn game points, the so-called XP. An educational feature in the game is the PokéStops. By spinning these stops the gamer earns items usable in the game. These stops are linked to real-world locations in the physical surroundings (e.g., historical buildings, statues of famous persons, or other landmarks) (Fig. 10.3). In other words, besides affording walking in the

Fig. 10.1 A screenshot from the Pokémon GO game including a player using a Pokéball to catch a Pokémon

Fig. 10.2 An example of the gaming interface; a screenshot from the Pokémon GO game including a map that features the gamer's avatar, buildings, one Pokémon, five PokéStops, roads, and a Pokémon Gym

surrounding vicinity, the location-based PokéStops provide additional in-game educational content to the orchestration.

DGBL has experienced a rapid expansion during the last decade and has at least four different branches today: (1) DGBL to support social inclusion of disaffected youth (Bleumers et al., 2013), (2) DGBL based on learning through game construction (Mozelius & Olsson, 2017), (3) DGBL based on playing educational games (Papastergiou, 2009), and (4) DGBL with the use of commercial-off-the-shelf (COTS) games (Blunt, 2007). This study was carried out according to the fourth branch. However, this does not imply that all COTS games are appropriate for educational settings. There often exists a need for curriculum alignment (Charsky & Mims, 2008). Even though COTS games are developed almost entirely for entertainment purposes, there are many examples of intellectually challenging content. Pokémon GO is an example of a COTS game which is free to download and play, but commercial in its use of the freemium business model in which players can

Fig. 10.3 A screenshot featuring an example of a PokéStop, a statue of Elias Sehlstedt

purchase additional in-game items (Paavilainen, Hamari, Stenros, & Kinnunen, 2013). In Pokémon GO, such items are purchased with the use of PokéCoins. These coins may either be bought with real money or earned within the game.

Orchestration as an Emergent Practice for Teaching and Learning in the Digital Age

Scholars within the field of educational technology, such as Instructional Designers or Learning Scientists, refer to teaching and learning as being orchestrated (Littleton, Scanlon, & Sharples, 2012). The metaphor of orchestration includes the coordination of resources with the intention of enhancing and bridging learning within as well as beyond the classroom. It embraces technologies, educators, lesson plans, and the utilization of time and places through meaningful educational activities in ways that should guide the learners towards an intended learning outcome (Howland, Jonassen, & Marra, 2012).

Some educational researchers view orchestration as a phenomenon wherein teachers manage school activities to achieve the intended learning (Bezemer & Kress, 2015; Littleton et al., 2012). However, it can be argued that students are engaged in planning, performance and management as well. From such a perspective, they are co-creators of their world and therefore participants in the orchestration of their own learning. Together students and teachers form a community of practice that orchestrates learning and teaching (Wenger, 1998). In such practice, co-design of educational activities is emphasized. As discussed above, emphasizing students as co-designers of teaching and learning in an emergent practice of orchestration finds supported in research of modern childhood. Such support is also linked to the societal development. Scholars such as Bond (2014) claims that mobile Internet technology is embedded in modern childhood and is something that is entwined in children's everyday life. Thus, mobile technologies are now essential in the social and cultural constructions of childhood. This development indicates that mobile technologies are an integrated aspect of the child's learning processes. Such a new quality of digitalization has effects on the activities of both children and teachers in school settings. In other words, from a perspective of recent societal development, both students and teachers became co-designers in an emergent practice of orchestrating teaching and learning. That is the perspective of orchestration this chapter built on.

For teachers, the digitalization of schools means a pressure to change how they look on classroom teaching and how they design for learning (Bezemer & Kress, 2015; Littleton et al., 2012). It emphasizes a need for teachers to go beyond the traditional practices of planning lessons and acting as distributors of knowledge, embracing as well the role of designers of learning opportunities (Jahnke, Bergström, Mårell-Olsson, Häll, & Kumar, 2017). Therefore, considering the concept of design in education, digitalization enables designing for new modes of learning and teaching. These new digital educational conditions change teachers' relation to the practice of teaching. In a time pervaded by accessible digital and mobile technologies, both teachers and students become designers of the educational activities (Bezemer & Kress, 2015). For example, student could be involved in designing educational activities that involves their own mobile devices. Moreover, digitalization can turn children into experts in their own lives, since they have access to information that in previous years only were accessible for teachers or other experts. Searching and applying such information could be included in the design of educational activities (Bond, 2014; Jaldemark, 2018).

In this study students and teachers became co-designers in an emergent practice of orchestration. Therefore, learning is viewed as a collaborative phenomenon including a practice that involves both students and teachers (Cerratto Pargman, Jahnke, Damsa, Nussbaum, & Säljö, 2017; Wenger, 1998). Such perspective on learning has been studied extensively during the last decades. The study builds on social aspects of learning, focusing on the importance of its communicative aspects and how resources in the surrounding vicinity support this process. In other words, learning is conceptualized as a phenomenon linked to practices in the surrounding community (Wenger, 1998). Finally, the approach of this study has been to apply technologies in terms of mobile devices and digital games to support a sense of togetherness among students and teachers (Dillenbourg, 1999; Sharples & Spikol, 2017; Traxler & Kukulska-Hulme, 2016). The following section briefly unfolds the methods applied in the study of the emergent orchestration of game-based learning in a middle school setting.

Methods

The study was implemented in two case units—a fifth grade and a sixth grade class. These two case units included two teachers and 20 students, ten in each class. The teachers of these classes planned one lessons series each—for the fifth grade class in social science and for the sixth grade class in mathematics—in which students were expected to work both indoors and outdoors using smartphones and the game Pokémon GO. In this study, "the outdoors" relates to the physical setting of the school's vicinity. The outdoor sessions included 30 min of walking in small groups during which the teachers planned to teach at the location-based PokéStops (these stops are described in the next section).

During the walks and follow-up sessions, the teachers and the students wore spy glasses. These glasses were equipped with video- and audio-recording functionalities and enabled the capturing of communication and visual fields from the perspectives of both students and teachers (Jaldemark, Eriksson-Bergström, von Zeipel, & Westman, in press). In combination with the spy glasses, a simple hand camera has also been used to get a complete picture of the design of the lessons and the way it was orchestrated in the class. The study embraced roughly 13 h of video data. This data was analyzed in two steps. The first step included a transcription of all video sequences. In the subsequent step, the sequences of the spy glasses and the handheld camera were combined and compared to get a holistic view of the sessions. These steps allowed a video analysis that embraced both perspectives of the individuals and the groups (Jaldemark et al., in press).

Immediately in connection with each outdoor session, semi-structured group interviews were conducted with the students to capture their experiences and perceptions of each activity (Eriksson-Bergström & Jaldemark, 2017; Mozelius, Eriksson-Bergström, & Jaldemark, 2017). These interviews resulted in approximately 2 h of data and embraced what students considered about the walk, what they thought they had learned and what they liked about wearing the spy glasses. The data-driven inductive thematic analysis of Braun and Clarke was applied in the analysis of the group interviews. Therefore, the analysis comprised the following phases: (1) becoming familiar with the data, (2) generating preliminary codes, (3) identifying patterns and themes, (4) reviewing the themes and patterns, (5) defining and naming categories, and (6) presenting the analysis.

Teachers' reflections have been captured through informal interviews that made it possible to describe how they perceived implementation of mobile technologies in the design of the lessons. What follows below are illustrations of how the orchestrations unfolded. Additional data were taken from the lesson plans the teachers worked out to orchestrate the different sessions.

The Study: Location-Based Games on Mobile Devices to Enhance Learning

The two different teachers involved in the study each orchestrated a lesson plan including both indoor and outdoor lessons. Indoor lessons included preparation and follow-ups. The outdoor lessons featured walking sessions related to PokéStops in the vicinity. During the walking sessions, students were divided into groups of 3–4 students (three groups in fifth grade and four groups in sixth grade). Each of these sessions included one teacher and one of the groups. In these groups, students were supposed to work with their smartphones in subgroups of two or three students. The size of these subgroups depended on the availability of devices in the groups.

Preparing Outdoor Sessions and Follow-Ups

During preparation, the teachers built a lesson plan including four different PokéStops (e.g., Figs. 10.2, 10.3, and 10.4), where the teachers planned to integrate content from the surrounding vicinity with the game. These stops included three statues of famous persons and one of the most important historical buildings in the city.

The teacher that planned for the mathematical walking sessions orchestrated involvement of the students during preparation. Students were invited to think about different items that could link Pokémon GO to the subject of mathematics. The result of this orchestration was 12 different tasks (or missions) for the walking component. One task could be, for example, "You have 400000 XP and need 200000 XP to level up. What percent of XP have you received and what percent have you left until you reach the next level?" Another mathematical task prepared by the sixth grade students in their co-designing of the educational activity incorporated figuring out what proportion of the number of cars they can see on the way to the first PokéStop that were red. This particular task emphasized the relationship between the settings of the game and the setting in reality. From a perspective of orchestration, this relationship is interesting, as it could contribute to an awareness of how the connection between these two different modes of reality becomes visible for the students. During the walking activity, the students brought these tasks and were instructed by their teacher to gather information to solve the tasks.

Fig. 10.4 A screenshot featuring an example of a PokéStop, a statue of Bertil Malmberg

In the social science class, the teacher prepared the lesson plan and the outdoor session without involvement from the students. Except for the prepared issues, the walking sessions also included co-designed discussions of issues that turned up spontaneously from students and teachers. Such orchestration embraced capturing ideas that spontaneously came to their minds during the walk.

The Outdoor Sessions

One of the PokéStops during the walking session was a statue of a famous poet (Fig. 10.4). As the groups approached the PokéStop, the teacher tried to attract their attention to what defined the PokéStop.

In the video recordings, it became visibly apparent that some of the students kept their focus on the screen even though the teacher told them about the information related to the PokéStop.

Teacher: Who is Bertil Malmberg then? Does anyone know that?
Student 1: He made the first books in this city.
Teacher: Yes, yes, he was a writer anyway.
The teacher reads facts on the sign. Student 2 and Student 3, who have the phones, are dealing with these and looking down at their screens.
Teacher: He is a member of the Swedish Academy. They award a prize each year. Do you know which prize it is?
Student 2: The Nobel Prize in Literature.

It is obvious that the teacher must have both skill and patience when it comes to catching the students' attention and making them not to focus on the game for a while. For the teacher, it is an art of balancing the planned aspect of the orchestration in terms of giving students the information planned for the PokéStop and following students' initiatives, for example, catching Pokémon or taking alternative routes to pass nearer to more desirable items such as a PokéGym. The following excerpt is one example of this:

Teacher: Guys, what's this PokéStop then?
Student: Oh, three Pokéballs!
Teacher: But, hey! What's the name of this PokéStop then?
Student: Here's the PokéGym!
Teacher: He has got a street named after him on the other side of the city.
Student: Check out this Pokémon!
Teacher: Yes, a street on the other side of the city.
Student: Hey you, check it out! Check out this Pokémon!

The second PokéStop on the walking sessions was another statue of a famous poet (Fig. 10.3). The orchestration incorporated an introduction by the teacher about the poet and how he was linked to the city, followed by the students listening and asking questions. Issues discussed at this stop included the history of the city and the poet, literature written by the poet and the impact of the poet on the city, including geographical issues of his birthplace, where he lived, and a street named after him. Although the primary subject of this outdoor session was social science, aspects of other subjects including mathematics were included in the orchestration, as shown in the following excerpt:

Student: And then you tick it, and then you take it, push it now, press now. Oh, you got a 5-km egg.
Teacher: And then you have to walk 5 km? But how long does it take to go 5 km then?

At the mathematical walking sessions, the students did pay attention to the tasks they had prepared besides the focus they had on the game. They were, for example, motivated to count all the cars they passed between PokéStops. One student in a subgroup had the mission to take notes, including information gathered towards being able to solve the tasks in the subsequent follow-up session.

At another stop, the Cathedral, the orchestration embraced discussions involving issues of civics, history, and religion. Among others, this PokéStop linked to issues such as how a war in the eighteenth century included the burning down of the Cathedral, and how the church is organized at a national level. The teacher wanted the students to reflect upon why the Cathedral in Swedish is called Domkyrka. What follows below is an excerpt that illustrates the discussion.

Teacher: Listen, we can think of that building too. (Looking at the cathedral) The big white one? What is it called?
Student 1: The church?
Teacher: Yes, it's not just an ordinary church.
Student 2: The cathedral.
Teacher: What does the cathedral mean then? What is the difference between an ordinary church and a cathedral?
Student 1: Has it anything to do with God?
Teacher: Yes, it has something to do with God. But what's the difference between an ordinary church and a Cathedral then?
Student 1: That's nicer … this is the only white cathedral in Sweden. And it's the smallest cathedral.
Teacher: Dean and Cathedral. This means that there are counties and provinces, the church is divided into dioceses.

The Follow-Up Sessions

The first step of the orchestration comprised preparing the outdoor sessions. The second step was the implementation of the class walks, followed by the last step which consisted of a follow-up session. Consequently, after the groups had participated in the outdoor sessions they met in the classroom a few days later for a follow-up session. During the follow-up sessions, the teacher both picked up issues that emerged during the walking session and issues that were prepared at an earlier stage of orchestration.

In the mathematics lesson, the orchestration embraced students working in pairs to solve the tasks they had designed in the preparation session. Students used a document including the tasks and the notes of the gathered information they took during the outdoor sessions. In addition to counting and solving the mathematical tasks, the students became engaged in discussions concerning the huge amount of cars they had counted while walking. Their reflections on the car phenomenon equaled awareness of sustainable development, and they reflected on solutions to environmental problems. These reflections from the students illustrate how innovative orchestration challenges the division of subjects in schools.

The orchestration of the follow-up session in social science started with the teacher handing out a factual text including summaries of information about the statues and buildings represented at the PokéStops. It included, for example, historical facts about the statues, facts, and photos of buildings (e.g., the Cathedral). Initially, the students read aloud from the text. This aspect of the orchestration could be understood and interpreted as pure reproduction of facts. However, it appears that the teacher through various issues followed up and expanded upon the students' understanding of the different phenomena that turned up during the outdoor session. They dealt with geographical aspects, on a national level but also related to the vicinity, such as street names named after one person represented by a statue they passed. The orchestration also embraced discussing the meaning of concepts such as county, dioceses, and provinces. During the students' reading of the text, the teacher made a few breaks to initiate a discussion of the meaning of different difficult language concepts. The orchestration also included the teacher asking questions to check how well the students remembered the facts from the outdoor session.

Teacher: You know these statues have given names to other things in society. Elias Sehlstedt, do you remember what he had named?
Student 1: A street.
Teacher: Yes, which street was it?
Student 2: Sehlstedtsvägen.
Teacher: Why was it just the Sehlstedtsvägen that he had named? Why no other street here on the island? Why just on that part of the city? What was the reason for that?
Student 1: He lived there, or they had their farm up there.

Besides students proving their remembrance of factual details from the outdoor sessions, it was remarkable that they remembered in detail how the walks were geographically displayed. However, when the teacher asked questions about facts, the students gave the right answers. Even if they had seemed to focus on the screen during the outdoor session, it did not seem to affect their attention to the content they were taught. Since it sometimes was visible in the films that they seemed to be unobservant to what the teacher had wanted them to focus on, the follow-up lessons were important to show that the factual skills the orchestration aimed at actually were achieved.

Implications for Learning and Teaching with Location-Based Games on Mobiles Devices

The current study included an application of mobile devices and digital, the so-called commercial-off-the-shelf (COTS), location-based games like Pokémon GO in a middle school educational setting. This application was related to both students and teachers efforts in an emerging practice of orchestrating teaching and learning. Even though teachers had the main responsibility for the teaching, students were involved in orchestrating the preparation sessions, the outdoor walking sessions, and the follow-up sessions. An implication of such shared practice of orchestration is that the outdoor setting affords the possibility for the teachers to include and follow both spontaneous and planned ideas from the students. In short, emphasizing students as co-designers by involving them early in the preparation phase was valuable, and could be used as an approach for teaching and learning. Another implication from the shared and emerging practice of orchestration is the possibility to implement mobile COTS location-based games like Pokémon GO in a middle school educational setting. Such deployment includes involving students' personally owned mobile devices, a so-called bring-your-own-device approach. Applying such resources in the orchestration of the educational activities added possibilities to blur the boundaries of time and place in ways that a traditional classroom setting constrains. A third implication of the shared and emerging practice of orchestration is that walking sessions together with location-based games and mobile devices help students link ideas from the surrounding society to the formal educational setting. Themes that were apparent during the walking sessions were later discussed in the follow-up sessions. These discussions included both planned themes as well as spontaneous themes that turned up during the walks.

To conclude: the study reported how two teachers worked together with their students in an emergent practice of orchestrating teaching and learning. This orchestration embraced location-based games and mobile devices in a Swedish middle school educational setting. By adopting a popular mobile COTS game, the teachers showed creative ways of orchestrating learning processes by linking the learning process of students to resources in the surrounding vicinity. Teachers linked content of schooling with the game Pokémon GO, a location-based game that is a common phenomenon entwined in the everyday lives of many students. This result suggests that orchestrations of educational settings may benefit from building links to students' everyday phenomena, for example, location-based games and mobile devices.

However, application of the results from this study is not a guarantee that all students will concentrate on the given task; just as in the orchestration of an ordinary classroom setting, students lose their concentration. Therefore, well-reasoned orchestrations are needed to reach good enhancement of students learning. Nevertheless, most of the students' learning seemed to benefit from combining indoor and outdoor sessions. Like in ancient Greece, it seems that walking sessions can stimulate discussions and collaborative learning activities such as discussing historical persons or mathematical problems. When Plato claimed that play and physical activities were educational, it was seen as radical for his time (D'Angour, 2013). Today, in the twenty-first century, it might be radical to question the idea of linking the learning process to a sitting position (Gitz-Johansen, Kampmann, & Kirkeby, 2001). More research is needed to understand how the combination of location-based games and mobile devices impacts learning and teaching in schools.

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Part III
Discerning Material Conditions in Informal, Outdoor Learning and Learning in the Wild

Chapter 11
The Impact of Materiality on the Design of Mobile, Augmented Reality Learning Environments in Non-formal, Outdoors Settings

Eleni A. Kyza and Yiannis Georgiou

Abstract The design of learning activities that are supported by Augmented Reality (AR) technologies is on the rise. As the field is still new, there is a need to consider optimal designs to enable and facilitate student learning. This chapter discusses the socio-material aspects of effective learning with AR technologies. A review of the extant literature indicates that material conditions are often ignored when discussing optimal learning in informal settings. We argue that designing for optimal learning should attend to the relations between humans, technology, and the environment—that is, it should carefully consider characteristics of the participants, the affordances of the AR technologies which are bounded by the material conditions, and the nature and goals of the learning activity. To support our argument, we present data from two case studies with the *TraceReaders* AR platform in the context of a broader design-based research project, that illustrate how the intended design of AR-supported learning is transformed by the interactions between the components of the triadic system. The chapter concludes with a discussion of design principles that consider aspects of materiality during learning with AR technologies using mobile devices in outdoors settings.

Introduction

Augmented Reality (AR) technologies enable the blending of the physical and the virtual world, by superimposing layers of digital and multimodal information on the real world. Even though AR spans several decades of development already, with

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the first AR systems appearing in the 1960s, only recently has it begun shifting from the sidelines to the forefront of technological development, with companies like Apple and Google releasing their own development frameworks for mobile devices in 2017.

AR holds promise in educational settings, as it is argued that it can provide just-in-time information, increase students' immersion, and support learning (Georgiou & Kyza, 2018; Wu, Lee, Chang, & Liang, 2013). For instance, in a review of selected empirical papers investigating the use of AR technologies in science education, Cheng and Tsai (2013) concluded that there is evidence that AR can support several facets of learning in science, such as conceptual understanding, spatial cognition, and the development of practical skills. Mobile AR, usually run on smart devices, such as mobile phones and tablets, can foster learning anywhere, anytime, and can have positive impact on learning at informal learning settings such as archaeological sites (e.g., Efstathiou, Kyza, & Georgiou, 2018) and museums (e.g., Yoon, Elinich, Wang, Steinmeier, & Tucker, 2012).

Despite the promise, research on the impact of AR in educational settings it still nascent, as attested in recent review papers (Akçayır & Akçayır, 2017; Bacca, Baldiris, Fabregat, Graf, & Kinshuk, 2014; Cheng & Tsai, 2013). The empirical studies included in these reviews primarily present data on the interactivity of the AR systems, how the use of AR can impact student learning outcomes and cognition, or how it can influence student motivation. At the same time, the empirical articles identify several challenges in implementing AR in education, such as difficulties in using the technology because of interface design (Munoz-Cristobal et al., 2015), experienced cognitive overload (Dunleavy, Dede, & Mitchell, 2009), as well as technical issues and bugs threatening meaningful participation, such as the accuracy and sensitivity of GPS in location-based AR (Cheng & Tsai, 2013).

AR contexts present new challenges for learning design that should be addressed for a successful learning experience (Dunleavy et al., 2009). While many of the challenges identified in the literature point to the need to attend to the design and orchestration of the learning activity while using this novel, for education, technology, only a few studies in the literature explicitly address issues of instructional design. For instance, Yoon et al. (2012), who investigated scaffolding approaches to AR use in informal learning settings, concluded that such settings present their own challenges to learning, alluding to the role of the physical setting in transforming the learning experience, and the importance of accounting for its affordances and constraints, when designing AR learning activities.

Our examination of the extant literature also leads us to conclude that most published literature discussing the potential of AR in educational settings tends to set aside the socio-material aspects of the experience, how the interaction between the learner(s) and the material conditions alter the participant's experience, and how the orchestration of the educational activity can be designed to optimize learning. This chapter seeks to address this issue of materiality in designing for productive

AR learning experiences, drawing from the findings of a design-based study with a location-based mobile AR activity for secondary school students in non-formal settings. We approach our work using the analytical lens of affordances and constraints (Gibson, 1977) of the specific technologies, and examine issues of materiality and instrumented activity (Verillon & Rabardel, 1995).

Materiality in Mobile AR Settings

In this chapter, we take a design-based approach to examining materiality in the context of location-based mobile AR environments intended to support student engagement, collaboration and learning in outdoors inquiries. The development of human cognition is shaped by the interactions with the environment, yet most studies of cognitive development remain at the epistemic level, ignoring the pragmatic level at which technology mediates the perception of reality and influences the construction of knowledge (Verillon & Rabardel, 1995). To date, these ideas still ring true, as researchers point out that, despite the increase in discussions about the role of materiality in the design of educational experiences, taken broadly, materiality is still pushed to the background and perceived as a means for achieving educational goals, rather than as an agent that can transform the educational experience (Fenwick, Edwards, & Sawchuk, 2015; Sørensen, 2009).

Verillon and Rabardel (1995) have argued that ignoring the socio-material relationships between technology and humans, undermines the efforts to understand and guide the use of technology in education. According to Verillon and Rabardel, artifacts shape and transform human cognition; this argument is more easily understood if we consider the technologies that modern people use to achieve everyday tasks—most, if not all, modern day amenities exist because of artifacts (technologies) enhancing the capabilities of humans. Along the same lines, Hollan, Hutchins, and Kirsh (2000) referred to a new theory of cognition, “distributed cognition,” which “extends the reach of what is considered cognitive beyond the individual to encompass interactions between people and with resources and materials in the environment” (p. 175). Not adopting a distributed cognition perspective misses on the opportunity to critically examine and understand the transformation of the activity as a result of an interacting system. Verillon and Rabardel have discussed this interacting system extensively and have proposed the “Instrumented Activity Situations” (IAS) model to capture the relationships in this system. The three main characteristics of IAS are the subject (i.e., the learner), the instrument (i.e., the app or technology used), and the object (i.e., the goal of the activity).

The use of mobile AR in education is a novel but alluring endeavor, as it comes with promises to revolutionize learning, by offering enriched, hybrid experiences; its study can enable a more systematic approach to the design of learning experiences in both formal and informal settings. Materiality is extremely important in AR, as AR pivots at a fine balance between the purely physical experience of the natural world and the purely digital experience of a virtual environment disconnected from the material world (Milgram, Takemura, Utsumi, & Kishino, 1995). This dynamic nature of AR, and the continuous interplay between the virtual and the real, makes the study of the socio-material conditions imperative. In AR inquiry-based learning contexts, we employ an adapted IAS model as a conceptual framework for analyzing learning interactions, with the three constituents being the ***students*** (subject), the ***AR technology*** (instrument), and the ***problem solving activity*** (object). In this context, technology should be perceived as consisting of the mobile device, its affordances, including its activity structuring potential, and its associated practices. As evidence about the potential of AR technologies for learning is still amassing, understanding the interactions between the three constituents of the triadic system, and especially how the triadic interaction may be shaping the learning experience in anticipated, but also unanticipated ways, is important to the principled design of AR for promoting deep learning.

A Case Study: The *TraceReaders* AR Platform

The *TraceReaders* AR platform (Georgiou & Kyza, 2013) was designed to support experiential learning and reflective inquiry in situ (Kyza & Georgiou, 2018). This effort was a continuation of prior efforts with STOCHASMOS (Kyza & Constantinou, 2007), a web-based, reflective inquiry learning and teaching platform. STOCHASMOS was a scaffolded environment, whose design enabled students to engage in collaborative articulation of data interpretations, scaffolded the identification and interpretation of online data as evidence, and ultimately supported students in developing evidence-based explanations of socio-scientific, data-rich problems (Kyza, Constantinou, & Spanoudis, 2011). Subsequent work with the *TraceReaders* platform sought to similarly support students as they engaged in inquiry-driven, outdoors investigations, while also implementing the design principles accumulated during the extended, design-based research with the STOCHASMOS platform. These key principles included scaffolding students' learning, engaging students in problem-solving, enabling them to collect data and develop evidence-based investigations, and supporting collaboration, articulation, and reflection.

As we designed the *TraceReaders*, the nature of practices, which were proven effective in classroom collaborations, were modified to adjust to the material demands of the new settings, where this technology would be used. Among others, these modifications altered the duration of each problem-solving activity, the type of scaffolding that could be used, the learning tasks and the culminating tasks, the nature of students' collaboration, and the role of the teachers. In addition to instructional design modifications, to be able to research these new mobile learning contexts, new methods for collecting interaction data in situ needed to be explored, such as using action cameras to collect rich interactional data in outdoors settings (Kyza, Georgiou, Souropetsis, & Agesilaou, 2019). These transformations of the activity should be expected, according to the theory of instrumented activity (Verillon & Rabardel, 1995), as the constraints of the technology can decide the range of epistemic actions that can be undertaken, but actions are also dependent on how the learner makes sense of the afforded activities.

In the next sections we first outline the design of the "Mystery at the lake" location-based AR app which was developed on the *TraceReaders* platform, with an emphasis on explaining the design intent. We then continue with a presentation of findings from empirical studies that indicate how the *design intent* was transformed by the emergent interactions in the IAS triadic system, and conclude with a discussion of the design implications of this work.

The Intended Design

Brief Description of the AR Activity

The "Mystery at the lake" location-based AR app (Fig. 11.1) was designed to engage middle and high school students in an inquiry-based, environmental science, narrative-driven investigation. During this activity, students' work centered on an explanation-building process about a problem-based environmental case related to

Fig. 11.1 The "Mystery at the lake" AR app. The figure shows what students saw in the physical environment, while on the top right corner one can see the interactive map with the hotspots

the aquatic ecosystem; in particular, students were asked to investigate the decline of the mallard duck population inhabiting the lake. While at the lake, students worked in pairs sharing a tablet equipped with Global Positioning System (GPS). The AR app included data, such as documents, images, diagrams, and videos, all related to the environmental investigation; the data augmented the real-world experience and were activated as students approached different hotspots around the lake. The activity script placed students in the role of environmental investigators, set to identify and interpret data provided by several video-based characters in the app, in order to develop an evidence-based explanation regarding the environmental problem they were investigating. By the end of their investigation, students were asked to present an evidence-based explanation of the problem in the form of a video.

Students navigated the physical space with the help of the hotspot map (shown on the top right of Fig. 11.1), which was digitally overlaid on top of the view of the physical location, with each hotspot activating a set of multimodal information once within a 20-m radius. Figure 11.2 presents an example of the digital overlay of information students would see once a hotspot was activated.

In designing the activity, and prior to the first implementation, an affordances analysis (Gibson, 1977) was performed; this analysis focused on the material conditions of the activity, which were compared to similar inquiry tasks with desktop computers in the classroom. According to Greeno (1994) an affordance is an element in the environment that contributes to interaction; however, affordances and abilities are two interdependent concepts; he proceeds to say that "*an affordance*

Fig. 11.2 An example of an activated hotspot overlaying digital information about the mallard ducks, as seen through the tablet's camera

relates attributes of something in the environment to an interactive activity by an agent who has some ability, and an ability relates attributes of an agent to an interactive activity with something in the environment that has some affordance" (p. 338). Gibson's affordances can be seen as inherent to the concept of instrumented activity, as they portray the space of possibility of a technological artifact; in other words, affordances suggest what is possible but also what is not. In turn, the psychological perception of these affordances by the learners creates the space of instrumented activity.

Kirschner, Strijbos, Kreijns, and Beers (2004) discussed three types of affordances in technologically mediated learning environments: technological, social, and educational. To these three, we add one more—environmental affordances—which is relevant to the context of the AR activity (see Table 11.1). In location-based AR learning environments, the *technological affordances* refer to the usability of the AR technology; *social affordances* describe characteristics of the learning system that invite social interaction and collaboration; *educational affordances* focus on characteristics that bound the types of learning that could take place; finally, *environmental affordances*, refer to those characteristics of the location, that can support social and educational affordances.

Kaptelinin and Nardi (2012) have put forward a mediated perspective of affordances. For example, in the context of inquiry with desktop computers, we observed that a coordinated set of scaffolds supported students' written elaboration of explanations of scientific phenomena, which were also accompanied by supportive evidence. This is afforded by the interaction between learners and technology, as the temporal and physical arrangements allow for time to reflect, examine data, discuss evidence, and articulate evidence-based explanations without many distractions. In the mobile AR activity, we hypothesized that the environmental distractions, the mobile nature of the activity, and the constraints of the tablet devices would not support extensive discussions, would not allow much time for reflection at the end of the activity, or would not be amenable to extensive typing to articulate explanations. Therefore, in addition to seeking to scaffold students' work by embedding a data capture tool and a notepad tool to facilitate students' on-the-go articulation in the *TraceReaders*, we also sought to take advantage of the tablet's touch screen and created a concept mapping tool to support students' recording of their collaborative conceptualizations of the phenomenon they were studying. Furthermore, we

Table 11.1 Types of affordances in mobile AR settings (based on Kirschner et al., 2004)

Type of affordance	Indicative issues to examine
Technological affordances	Are the system actions easy to use and user-friendly? Are actions easily identifiable and can they be performed in the most intuitive and efficient manner?
Social affordances	Does the system allow and invite collaboration and exchange of ideas?
Educational affordances	Does the space of possible actions promote learning?
Environmental affordances	Is the environmental setting conducive and supportive to engaging learners in the desired behaviors?

changed the explanation task, and asked students to record a video explanation, instead of typing it. The task was intended to support reflective thinking, and avoid the technological constraints created by the small digital keyboard and the continuous movement in the physical space.

In the case of this work, affordances should be seen as emerging in the interactions between the system (learners, technology, goals), which is what we explore in the next section. Were the modifications in the learning activity, as a result of the analysis of the triadic system, successful? For this, we turn to the empirical study and its findings, so that we can better examine the participants' perceptions of their interactions with the socio-material system.

The Enacted Design

Research Design

The participants of this study were two cohorts of 11th grade students ($n1 = 18$, $n2 = 10$) enrolled in a week-long summer club. The study adopted a design-based approach, with the first iteration providing the data for the revision of the learning tasks. During the first iteration, nine pairs used the first version of the location-based AR app to investigate the problem-based case and develop an evidence-based explanation; five pairs used the revised version to solve the exact same problem during the second iteration.

Data were collected during and after the AR activity at both implementation rounds. In this chapter we report on data collected from field notes during the learning activities, and from students' reports of their own experiences. The latter were collected during two 90-min group interviews, using the nominal group technique (MacPhail, 2001). According to this technique, students were initially asked to individually write down and justify their viewpoints regarding their learning experience during the location-based AR activity (likes, dislikes, challenges, engaging and disengaging aspects, etc.). Students were, then, asked to share their ideas with the group; the interviews concluded with a debriefing discussion. In this way, individual input from all group members was obtained while also having access to richer discussions resulting from group interaction on the topic. The data were analyzed to identify main themes relating to the materiality aspects of the AR activity, using a thematic analysis approach (Attride-Stirling, 2001).

Emergent Interactions

Using AR technology at an outdoors site, such as a local lake, was both an opportunity but also a challenge for the students. Both the natural environment, the mobility inherent to the AR location-based activity, and the characteristics of the mobile technology (tablets) on which the *TraceReaders* AR "Mystery at the lake" app run, provoked several unforeseen events, resulting in a set of emergent interactions, which affected the realization of the design of the location-based AR learning activity. These emergent interactions are discussed in the following sections in relation to the materiality aspects of the outdoors location and the technological equipment employed.

Iteration 1: Interactions between the physical location and students' immersive experience

The outdoors investigation positively contributed to students' enthusiasm and motivation to learn, especially at the beginning of the learning activity. According to the students, the outdoors provided an intriguing departure from the traditional school lessons, which are restricted within the classroom walls. In particular, as students reported, the situated and outdoor nature of the activity allowed them to experience a sense of agency and freedom as they had the opportunity to walk around and explore the lake, rather than passively sitting in front of a computer. They enjoyed the scenery and were motivated by the fact that they had the opportunity to investigate an environmental case at the place where it had unfolded. In one student's own words: "*The most important thing for me was that I was not stuck in front of a laptop… I was walking, I was doing things, I was looking around me… I was feeling as I was inside this game… It was something different…*" [SP, Boy, First iteration].

However, the location also yielded a set of constraints, which negatively influenced the learning experience. Based on empirical observations and according to the students themselves, the intended interactions were influenced by environmental distractions, such as external noises (e.g., provoked by nearby farming tractors), birdwatchers visiting the lake, planes flying over due to a neighboring military airport, insects or lizards. In addition, the geographical features of the site (rugged terrain and slippery ground by the lakeshore), made students anxious as they felt responsible for the safety of the equipment. All of these factors were intervening in the learning process as they were distracting students during the activity. For instance, one of the students in the first iteration stated that "*There was a huge lizard in our way that derailed us… When we saw the lizard, we decided to take a different path. We had to return back and start from the beginning.*" [GS, Girl, First iteration].

Environmental factors also negatively impacted the learning process, as expressed by the students themselves. In particular, screen glaring limited the readability of the screen due to the bright daylight. As a result, students had to search for shade in order to have a better view of the app content. In addition, warm weather contributed to student fatigue. As a result, students admitted that, by the end of the activity, they became disengaged with the culminating task of preparing a video to present an evidence-based explanation for the problem they were asked to solve.

Iteration 1: Interactions between technology, learning tasks, and learning process

The use of the tablets and working in pairs for solving the environmental case in the context of the "Mystery at the lake" AR activity was, according to the students, a unique and innovative experience. As students reported, the location-aware nature of the app made them feel as actors within a digital game, which was mediated by their tablets. In particular, the students were excited with the functionality of the interactive map, which would reveal their changing position within the real world in relation to their distance from the hotspots. Furthermore, the affordances of the app to augment reality with digital data at each hotspot, allowed students to gather just-in-time information.

During the first enactment of the "Mystery at the lake" AR activity, students indicated a dissatisfaction with the loose coupling between the virtual and the natural world, since their interactions at each of the hotspots were, primarily, with the digital content displayed by the tablets. As one student said "*There should be a more realistic representation of the evidence. We should also have some more tangible data, rather than collecting all of the data from our tablets.*" [DP, Girl, First iteration].

Students also reported that the expectation to annotate data on the tablet, using the notepad and the concept mapping tool, was not practical, and requested different methods for documenting their work. As one student said "*We did not really employ the concept mapping tool. Instead, what we did with my partner was to capture photos during the data collection and just kept short annotations of our hypotheses.*" [CC, Boy, First iteration].

Finally, the students indicated that their collaboration was limited by the size of the 10″ tablet they shared to access the multimedia content. It appears that the students who physically held the tablet paid more attention to the content. Other issues, such as not being able to hear the sound in the videos due to ambient noise, and technical issues (e.g., GPS stability and hotspot activation) were also reported. In particular, the fact that the app worked offline, since there was no internet connection by the lake, created some usability problems as the students could see the position of the hotspots as blue spots, but they did not always see the map or their own position.

Iteration 2: Interactions between the physical location and students' immersive experience

A number of revisions were undertaken to address the issues of fatigue, warm weather, and screen glaring, as a result of the students' input. For example, the complexity of the investigation was reduced by only focusing on two ecological phenomena (pesticide bioaccumulation and eutrophication). This resulted in fewer hotspots, a reduction in the information that students needed to investigate, and a reduction in the duration of activity by 30 min (90 min vs. 120 min during the first iteration). The locations of the remaining hotspots were also shifted to places with shade (such as at the inside space of a bird-watching tower). Tablets were also equipped with anti-glare screen protectors. These changes helped ameliorate the environmental distractions, even though they did not completely diminish them.

Iteration 2: Interactions between technology, learning tasks, and learning process

After receiving the students' input, the following revisions were implemented: First, the hotspots were purposefully placed at specific points of interest more tightly connected to the narrative (at the bird-watching tower by the lake, at the agricultural storehouse by the lake, on the shores of the lake where the mallard ducks build their nests, etc.). As such, in the revised version, the path that students had to walk along was better designed to fit the theme and the narrative structure. A different scripting was also evident in asking half of the pairs begin the activity from a different hotspots, in order to reduce noise and interruptions caused by other student pairs. Finally, more experiential activities were added, requiring students to collect environmental data from the physical environment. For instance, in addition to collecting data from the digital sources, students were also asked at several hotspots to consider data from the immediate natural environment (e.g., bird nest with duck egg shells, pesticide containers, etc.).

During the first iteration students pointed to a mismatch between the more fluid, mobile activity and the expectation to type on small tablet screen. To respond to this challenge, we changed the scripting of the activity, asking students to only use the digital data capture tool and take notes using pen and paper. To promote feelings of ownership of the activity we asked students to alternate roles at each hotspot, with the two roles being the user of the tablet and the note taker. In addition, all of the videos were replaced with videos of better sound quality and identified technical problems were addressed. Since students indicated that the outdoors investigation was tiresome due to the environmental conditions, and reflection was challenging due to hardware limitations, it was decided that students would be provided time to review their data and develop their final evidence-explanations upon their return to the environmental center.

All of these changes regarding the material aspects of the *TraceReaders* app, resulted in a more engaging learning activity for the students. Table 11.2 shows the

Table 11.2 Environmental issues flagged by the students in group interviews

		First iteration		Second iteration	
		N	%	*N*	%
Real-world scenery	Positive +	9	8.7	11	29
	Negative –	0	0	0	0
Mobility	Positive +	5	4.8	1	2.6
	Negative –	0	0	0	0
Hotspot arrangement	Positive +	0	0	0	0
	Negative –	12	11.5	0	0
Risks and dangers	Positive +	0	0	0	0
	Negative –	4	3.9	3	7.8
External distractions	Positive +	0	0	0	0
	Negative –	7	6.7	0	0
Real props	Positive +	0	0	18	47.4
	Negative –	20	19.2	0	0
Screen glaring	Positive +	0	0	0	0
	Negative –	5	4.8	0	0
High temperature	Positive +	0	0	0	0
	Negative –	42	40.4	5	13.2

percentage of statements that were received during the group interviews after the first and the second iteration for the environmental and location-based aspects of the learning interactions.

The students who participated in the revised version of the activity did not provide any further comments in relation to the augmentation of reality, the user-friendliness of the app, the scaffolding tools, the explanation building activity, or any relevant technical bugs. During the second group interview, the students highlighted how the naturalistic and mobile aspects of the activity had positively contributed to their learning experience. In addition, in the revised version, students did not provide any negative comments in relation to the hotspot arrangement or to the external distractions. Instead, they positively emphasized how the employment of real props had provided an interactive and engaging learning experience. In a student's own words: "*Well, I have written down that this activity was not a simple data collection from a mobile device. We were not completely dependent on the tablet during our investigation as there was a direct contact with the physical place. The information provided was quite interesting and motivating for our investigation, as we could have a direct contact with the evidence that we collected.*" [DF, Girl, Second iteration].

Discussion

This chapter examined the role of materiality in the inquiry practices of high school students using the *TraceReaders* location-based AR technology. In this context, we explored a question set by Mifsud (2014) on whether, "the new material actually changes educational practice" or "does the practice transpose itself to another medium, extending the practices of the old material onto the new?" (p. 145). The findings of the study indicated several emergent interactions, which affected the realization of the intended design of the location-based AR learning activity and led to transformations of learning processes and educational practices. These findings can be explained by reference to the socio-material agency of the constituents of the revised triadic system we introduced at the beginning of this chapter, and which was based on Verillon and Rabardel's (1995) ideas on the socio-material system. The constituents of this triadic system were the ***students***, the ***AR technology***, and the ***goals of the problem-solving activity***, whose interactions led to affordances shaping the learning experience. We discuss these issues next.

The affordances of the activity situated in the physical space heavily influenced students' engagement with the learning tasks. These findings are in line with other discussions in the literature; for instance, researchers have argued that, in contrast to virtual environments, location-based AR is not only dependent on the virtual interface and content but also on the locality and context of the AR activity (Georgiou & Kyza, 2017; Kim, 2013). Several environmental factors contributed to these results, due to the mobile nature of the activity: moving around in physical space requires the use of human resources more radically than when sitting in front of a computer in a classroom for 45 min. The idea that human sensorimotor reactions are vital to meaning making is a central premise in psychological theories of embodied cognition, which has been defined as an approach that states that "the mind must be understood in the context of its relationship to a physical body that interacts with the world" (Wilson, 2002, p. 625). In our study the idea of embodied action has manifested itself in several statements during the group interviews. For example, students requested more tight coupling between their actions in the physical environment and their actions in the digital world. Another result of embodied action that negatively influenced the students' attention to learning tasks was the strain placed upon them by the taxing environmental factors, which hindered students from attending to important epistemic aspects of the task, such as composing an evidence-based explanation at the end of the activity.

The affordances of the AR technology, as manifested in the interactions between the technology and the participants, highlighted the potential but also a number of constraints that influenced the first iteration of the designed activity. On one hand, the collaborative use of the tablets to solve the environmental problem was, according to the students, a unique and innovative experience. However, and in agreement with the study of Dunleavy et al. (2009), hardware and software issues (e.g., the tablets' size and sound quality), challenged the problem-based learning process and limited the collaboration between the students. Even though we had anticipated that the affordances of the activity using mobile AR technology on tablets required a modification of the nature of the tasks that the students would be expected to work on, findings indicated that additional design-based research is necessary to ascertain the type of tasks that are most suited to the location-based mobile investigation and the forms of scaffolding that can effectively support these investigations.

The identification of the emergent interactions from the first iteration of the location-based AR activity resulted in its redesign; this allowed for a more engaging and effective learning experience for the participating students. The effectiveness of the revised location-based AR activity leads us to suggest the following indicative instructional design principles:

- Adopt distributed learning strategies, such as the use of roles, to address challenges brought upon by the misalignment of the mobile technology and the nature of the collaborative task;
- Couple the physical and the virtual environment, in order to achieve a carefully crafted blended world, which promotes learning through embodied actions;
- Carefully orchestrate learning activities, by using appropriate scripts and considering the affordances of the interacting agents;
- Prevent the negative consequences of embodied learning activities by considering environmental factors and their impact on cognitive processing capacity; for instance, the duration of the outdoor activity can lead to fatigue or cognitive overload;
- Attend to usability issues early (e.g., address GPS stability issues prior to the start of the activity, equip tablets with antiglare screens, take care of the audiovisual quality of the digital data), to avoid diminishing cognitive engagement with the task.

Conclusions

The study presented in this chapter explored aspects of the socio-material perspective of location-based AR activities, as these emerged from two iterations of the same mobile AR learning environment during an outdoors inquiry investigation. The contrast of the pedagogical practices during these iterations with practices in traditional schooling environments which share the same epistemic goals, indicates that the unique characteristics of location-based AR investigations require a different design approach. This approach should account for the emergent interactions and the deeply situated activity between participants, locality and the technologies at play. Future work should focus on evidence-based design frameworks that account for the socio-material interactions of all constituent components and which can create spaces for rich learning interactions.

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Chapter 12
Emergent Digital Multiliteracy Practices at the Core of a Museum–School Partnership

Stefania Savva

Abstract This chapter presents an instructional approach for undertaking museum–school partnerships in the twenty-first century in response to the increasingly multimodally mediated world we are living in. Employing a Design-Based Research (DBR) approach, this chapter describes the design, implementation and evaluation of a museum–school partnership that unfolded in 13 weeks for the design of a student-generated virtual museum to support STEM curriculum for K-12 primary education in the island of Cyprus. Findings from a combination of qualitative and quantitative methods of data collection, indicate that the museum–school partnership unfolded as an emergent multiliteracy practice. Students engaged in the learning process as active designers and multimodal learners; in such a process, they enacted repertoires of digital literacy that reflected critical thinking competencies and higher order thinking.

Introduction

This chapter uncovers the narrative of one empirically informed initiative to address the question: How can a museum–school partnership be designed and implemented to enhance the literacy repertoires, in particular, but not exclusively, for culturally and linguistically diverse (CLD) students? The intention was to introduce a theory-based, empirically tested framework for museum–school partnerships, in an attempt to propose, analyze and discuss a new emergent practice to support diversity and multiliteracies teaching and learning for the twenty-first century. Particular emphasis is given on how the unique nature of museums can potentially facilitate literacy learning of all students, regardless of their background.

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Background to the Research

There are a few key concepts that act as touchstones in this investigation. Throughout this chapter, I use the term literacy to refer to "the flexible and sustainable mastery of a repertoire of practices with the texts of traditional and new communication technologies via spoken, print, and multimedia" (Luke & Freebody, 2000, p. 9). Nevertheless, in this definition we incorporate a key proposition concerning the nature of literacy (adapted from Barton & Hamilton, 2000, p. 7): that literacy is productively understood as an open-textured category of sociocultural practice. Closely related is the notion of a "repertoire," which refers to a toolkit (Gutiérrez & Rogoff, 2003), "an orchestrated set of capabilities and dispositions for acting purposefully in the world" (Alloway, Freebody, Gilbert, & Muspratt, 2002, p. 127). In other words, repertoire refers to people's diverse ways of engaging and developing 'cultural capabilities' in different activities as a result of participation in a range of cultural practices (Pacheco & Gutiérrez, 2009, p. 74).

Concurrently, it is of equal importance to delimit how the term museum–school partnership is used in this research, to allow for a better understanding of the objectives and relationship developed between the museums and schools involved. For the purposes of this chapter, the term museum–school partnership will be used to refer to the goal towards which the intervention implemented aspires to reach, rather than the completed product of a fully formed partnership in the specific context. This research therefore describes the journey towards the ideal of collaboration and partnership through the programme implemented. Both myself as the museum educator and classroom teacher have contributed to the structure and content of the intervention (Freedman, 2011), as well as the implementation and evaluation of the intervention.

Importantly, the practical aspect of the activities involved in the intervention implemented during the fieldwork, entailed the use of the concept of virtual museums and how students engaged in designing their own virtual museum. Virtual museums are perceived as a multidisciplinary research field which is often linked with Technology Enhanced Learning (TEL) (Goodyear & Retalis, 2010; Jackson & Adamson, 2009; Prosser & Eddisford, 2004). These environments through their multimodal technologies provide new and fresh experiences of digital cultural heritage, or connect different museum collections (Cilasun, 2012, pp. 2–3; Giaccardi, 2006). Incorporating new media technologies to fulfill the museums' educational provision has been widely acknowledged by practitioners and museum educationalists (Anderson, 1999, p. 2; Dierking & Falk, 1998), yet it was not until the early 2000s that it gradually became part of constant dialogues in a European context for developing practice that meets the challenge of the digital divide (Parry, 2001) and cultivating the individual empowerment which derives from the free and equitable access to information (Abid, 2002).

Conceptual Framework

This research draws from a rich network of theoretical views, chief among them: sociocultural, socio-constructivist theories, and social semiotics. Working within the grounds of the theoretical conceptualizations discussed previously, the "Museum Multiliteracies Practice" (MMP) framework (Fig. 12.1) utilizes three interrelated pedagogies addressing learning for culturally and linguistically diverse students (Savva, 2016a).

Searching for a pedagogical model that addresses cultural diversity while encompassing the demands for the competent and flexible learners of the twenty-first century, I was introduced to multiliteracies pedagogy (New London Group, 1996, 2000). Cope and Kalantzis (2000) are among those who introduced the term "multiliteracies," and elaborated on the potentials of a "Pedagogy of Multiliteracies." A pedagogy of multiliteracies is posited as "a teaching and learning relationship that potentially builds learning conditions that lead to full and equitable social participation" (New London Group, 1996, p. 60). Cope and Kalantzis (2000, p. 239) stress that there is nothing radically new in a multiliteracies pedagogy; prevailing pedagogy has simply been repackaged in order to expand the scope for literacy by viewing many types of expression and communication as literacies, whether formal or informal; spoken, gestured, written or graphic; official or unofficial (Ryan & Anstey, 2003, p. 15).

Kalantzis and Cope (2005, p. 72) have extended the multiliteracies pedagogy through the Learning by Design model (LbD) which informs the MMP framework. Learning by Design is building into the curriculum the idea that not every learner will bring the same life experiences and interests to learning (Kalantzis & Cope, 2012), as well as acknowledging that every learner is not on the same page at the same time (Kalantzis & Cope, 2005). Anstey and Bull (2004, 2006, p. 34) identify these different domains or identities collectively as Discourse Worlds, and suggest that students draw on two in particular to make meaning, their Lifeworld and their School-Based World. These worlds overlap and inform one another. A truly meaningful multimodal integration in schools would require that teachers draw on the key components which comprise school literacies, and use them in combination with outside of school literacies for students to engage attentively with and for others to position themselves in the world.

The preliminary literature review for this research suggested that the goals and practice of multiliteracies pedagogy could be implemented in the context of museum teaching and learning to enable social inclusion and meaningful participation. Nevertheless, it was critical for the design of the MMP, "to re-conceptualise what constitutes museum education and museum literacy before addressing a creative synergy between the school and the museum" (Savva & Souleles, 2014, p. 121). Viewing museum as a learning arena, redefines the goals and strategies of educators in relation to their teaching and the museum curricula; such a view fits the incorporation of museum learning into the multiliteracies concept. In these conceptualizations of museum learning, it is imperative to consider also the introduction of digital

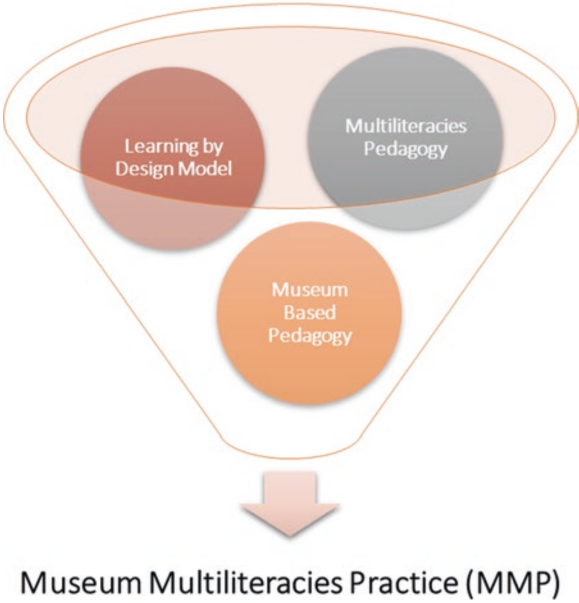

Fig. 12.1 The pedagogies interacting in the Museum Multiliteracies Practice framework (Savva, 2016a)

cultural heritage in the museum scene within the context of museums operating in a digital age (Parry, 2010). Because museum exhibits[1] make meaning through multiple media, multiple modes, and multiple symbol systems, the literacy practice of museum visiting can be also viewed as a multiliteracy.[2] Schwartz's (2008) work supports my theoretical proposition here. He proposed a museum-based pedagogy as opposed to traditional museum education.

Schwartz highlights that museum-based pedagogy differs, in that its main goal is "the teaching of verbal, visual, technological, social, and critical literacies (Fig. 12.2); not museum literacy, which is the ability to access the museum's cultural and intellectual resources" (Schwartz, 2008, p. 29; Stapp, 1984). Museum-based pedagogy, thus appears to be working within the affirmations of multiliteracies pedagogy. This contributes to acknowledging "the importance of social and material factors in determining students' empowerment and successes" (Schwartz, 2008, p. 29).

[1] The act of creating an exhibit is parallel to the act of producing knowledge.

[2] An interesting project is the "Museum Literacy Project" in 2008–2010 involving nine different museums, administrations, and training institutions based in five European countries, supported by the EU programme Lifelong Learning—Grundtvig Learning Partnerships 2008. The project focus was on museums and audiences with low schooling levels, and how museum literacy can be reached and maximize the museum experience for these audiences.

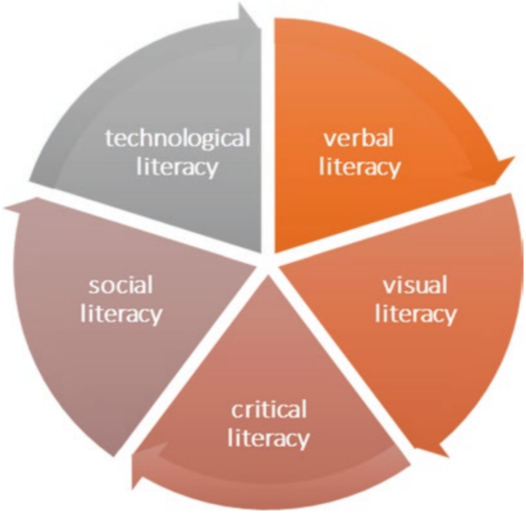

Fig. 12.2 The literacies in museum-based pedagogy (Savva, 2016b)

Research Design

To test the feasibility of the framework in a real life setting, a design-based research (DBR) methodology was utilized to undertake the research using both qualitative and quantitative data collection methods. DBR is an emergent paradigm of research which involves cycles of iterative development of solutions as applied to pragmatic and complex educational problems in schooling contexts (McKenney & Reeves, 2012). The approach can be characterized as intervention-centered, theoretically informed, goal oriented, iterative, mixed modality in design, and pragmatic (Reinking & Bradley, 2008, p. 17).

The research unfolded in three phases: the preliminary stage, the prototyping stage and the implementation and evaluation stage. In particular, an intervention, the Living Museum Partnership (LMP), was designed, implemented and evaluated in 2012, with a group of primary students coming from various cultural and linguistic backgrounds. The focus is on the experiences of four schoolteachers, two museum educators, and 36 primary students aged 10–12 years old in the island of Cyprus, engaged in the multimodal design of a virtual museum and a year-long museum project. It was decided to capitalize on situated practice by focusing on the need to deepen awareness about a local environment problem near the school area as part of the year of environmental awareness at the school (Savva, 2016a). Each prototype or cycle entailed particular developmental multiliteracies-based activities, although there was flexibility to adjust according to the participants' suggestions and needs. Thus, the curriculum itself was based on the world of students' designed and designing experiences, because they were engaged in meaningful and relevant literacy practices related to their sociocultural context. The intention was to develop and improve both end results of design research efforts: the educational intervention under development; and its accompanying design principles (Nieveen & Folmer, 2013, p. 156).

To assist interpretation, a hybrid methodology of qualitative methods of thematic analysis—identification of emerging themes (Daly, Kellehear, & Gliksman, 1997)—incorporating both inductive (data-driven) and deductive (a priori template of codes) methods was employed. To assess the effective design of the LMP intervention, the evaluation was based on the cognitive, interpersonal, group, resource, and institutional level criteria proposed by Collins, Joseph, and Bielaczyc (2004). The above intertwined criteria informed the data collection, analysis, and the interpretation during the assessment phase of the research. Each evaluation level had key indicators which were employed in the judgment of the impact of the LMP as summarized in Table 12.1.

Emergent Students' Digital Multiliteracy Practices Observed

In addressing the ways in which the LMP acted in terms of its contribution to students' digital multiliteracy practices, this section takes a closer look into one group's experience through a narrative approach to documented assessment termed

Table 12.1 The key indicators for judgment of the impact of the LMP and implementation of the new approach during the final intervention

Evaluation criteria	Characteristics	Data collection
Cognitive	Assessment of students' prior knowledge and evolution in thinking	Observations of students' visual representations (e.g., storyboard creations and mockup exhibition rooms) and verbal explanations. Print Evaluation sheet Rubric (online formative assessment scheme)
Interpersonal	Student-to-student interactions Student-to-teacher interactions	107 Observations during the fieldwork and 12 supplementary interviews field notes
Group	Group dynamics Engagement in the intervention: a sense of belonging	59 Observations and field notes.
Resource	Availability and use of print and multimodal texts	45 Semi-structured interviews and surveys
Institutional	School culture and parents' support; School leadership support.	16 Semi-structured interviews and surveys with staff

"learning stories" (Carr, 2001). In relation to learning stories, these draw on a sociocultural context and have been defined as including "situated learning strategies plus motivation—participation repertoires from which a learner recognises, selects, edits, responds to, resists, searches for and constructs learning opportunities" and, as "being ready, willing and able to participate in various ways" (Carr, 2001, p. 21).

This section provides a brief outline of the profiles of the three student participants in Group A coming from culturally and linguistically diverse backgrounds with varied learning levels and difficulties.[3] Before discussing their knowledge journey during the LMP, Group A students' literacy identities are profiled, to provide a glimpse of their past experiences with aspects of their existing literacy repertoire during everyday school activities, previous education, and socioeconomic and cultural background as individuals (Table 12.2). These insights were developed from intensive observation throughout the field study and from informal interviews with teachers and the students' families.

As shown in Table 12.2, the students in Group A had similar family and cultural backgrounds, and socioeconomic status. Their diversity was in terms of their different individual attributes evident also in an activity called "Diary Notes," enacted prior to the implementation of the LMP. Their interests ranged from art and fashion to music, football, and computers. These students were originally assessed by their teachers as belonging to the assisted competence level (Sergey and Olga) and the autonomous competence level (John). Following the enactment of the LMP, John reached the third and higher level of performance (collaborative competence level), while Sergey and Olga were mainly assessed as belonging to the autonomous level. The excerpts and discussion that follows, indicates these students' knowledge journey over the course of the LMP through the different literacy events.

The Learning Stories

Experiential Knowledge

The design of the induction session of the LMP involved connecting learning with the diverse life-worlds of the students through activities such as the "Mystery Box" which enquired into students' personal experiences with museums ("experiencing the known"), and reading and commenting on fictional characters' experiences of museums during the "Stick to it" activity ("experiencing the new"). The following excerpts are from a literacy event between members of Group A and the principal researcher, during the "Mystery Box" activity.

[3] Pseudonyms are used for all students mentioned in this research.

Table 12.2 Profiles of students in Group A

	Sergey	John	Olga
Family background	Both parents work Second born of three Christian Orthodox	Both parents work First born of two Christian Orthodox	One parent works First born of two Christian Orthodox
Interests/life-worlds	Music Football	Music Computers	Art Fashion
Preferred multiple intelligences	Kinesthetic Intrapersonal	Logical Linguistic Intrapersonal	Kinesthetic Logical
Academic performance	Low—prefers and excels in practical activities	High—enjoys solving problems, Excels in Maths and Science	Indifferent to most subjects except artistic ones
Literacy performance on MPAZ prior to the enactment of the LMP	Assisted level competence	Autonomous level competence	Assisted level competence
Literacy performance on MPAZ prior to the enactment of the LMP	Autonomous level competence	Collaborative level competence	Autonomous level competence

Seeing the box. Enthusiasm. Reluctance to discuss. Reading the questions for the group … [FN, Gr.5].
Hesitant and with difficulty…
Olga: What was the most impressive thing that you found in a museum? What did you like the most?
No answer.
John: Interesting things?
Researcher: Exactly.
John: Like … I've seen a big picture, it was nice, and it was so big.
Researcher: You mean like a painting?
John: Yes.
Sergey: The first iPhone.
Olga: The mouth of a shark.
Researcher: Where was that?
Olga: I was in a Russian museum…
….
John: What would you like to see in a museum? Hm, I know!
Researcher: Wait, let's see what the rest can think of first.
Sergey: I want to see a научная фантастика (science fiction in Russian)… *He turns over to John, who speaks Russian and tells him.*
John: Oh, he means like fantasy, hmm, like a science fiction museum.
Researcher: That's fantastic. Have any of you been to such a museum?
Olga: I have been to a movies museum. It was great!
John: It is not really the same but you can see science fiction in this sort of museums.

Through "experiencing the known," the teacher provided "access without children having to leave behind different subjectivities" (New London Group, 2000, p. 18). Even for Sergey and Olga, who were having difficulty expressing themselves, identified as belonging to the low-ability group of assisted learners, this activity enabled them to show aspects of their personal stories and seemed relaxed. Sharing their ideas within the group, allowed to benefit from John's abilities and knowledge as autonomous learner. The experiential knowledge acted as scaffolding[4] and encouraged engagement for these students. This entanglement with learners' identities is described by Kalantzis, Cope, et al. (2005, p. 37) as "belonging." They argue that "a sense of belonging is crucial to effective learning as it engages the learner's identity" (Kalantzis, Cope, et al., 2005, pp. 37, 64). Kalantzis, Cope, et al. (2005, p. 51), refer "to this engagement with learners' identities as the learner's knowledge, experiences, interests and motivation."

Through the "Stick to it" activity, students found out new information; this "new" knowledge soon became "known." Kalantzis, Cope, et al. (2005, p. 48) describe this as follows: "The place to which you travel becomes part of you, part of your repertoire of life experience, and in fact another aspect of your identity." The use of multimodal modes of literacy such as the PowerPoint, allowed to address students' identities and "realities of difference" (Kalantzis, Cope, et al., 2005, p. 51), such as experiences, interests and interpersonal styles. Supporting their "mental files" before reading (Keene & Zimmerman, 1997) with this sort of multimodal activity, facilitated students' learning and acted as a stimulating repertoire of "before reading" activity. Students should be able to consciously activate relevant schemas (prior knowledge) to comprehend new information from texts (Shallert, 1982).

Conceptual Learning

During the conceptual learning process of the LMP, the students following the guidelines provided in the WebQuest employed, were assigned a scientist role (Ornithologists, Aquatic Biologists, Zoologists). They researched online for information on endangered animals and their impact on their environment based on their "scientific field." Following this procedure, students completed a "Web of Life" print sheet, including fast facts about the chosen species. This was a *conceptualizing by naming* activity, as students explored concepts and developed specific vocabulary. The following excerpt is from this discussion between members of Group A and the principal researcher during the "Web of Life" activity.

John: I think we must start writing facts like its size, color, habits etc.
Olga: I am not sure. I think we should put it aside and first note about why the animal is endangered.

[4] Scaffolding (Bruner, 1975, 1983, 1986) is a metaphorical concept for an instructional approach which posits that teachers (as apprentices) accommodate students' individual needs through "the systematic sequencing of prompted content, materials, tasks, and teacher and peer support to optimize learning." (Dickson, Chard, and Simmons, 1993, p. 12).

John: Perhaps we can do both. Did you find any useful information so far? Sergey?
Sergey: I found this. Why it is called a carnivore, because it eats meat. Shall we put it?
John: Yeah, I think so, sure. And there is that point there, the diet, there, put it, see.
Sergey: Yeah … I understand.
John: So, first add this here so that we don't forget. Then, look at this about the anatomy, it's great.
Olga: Yes, we need this with that, gill slits. And the habitat, found near shore along most of the temperate
Sergey: Okay, I will write this too then here.

Following "The Web of Life" activity, students examined the effect of disturbances throughout the whole food chain using the "Consequences/effect wheel," where they thought and jogged down as many (direct) first order and (indirect) second order consequences they could think of "Animals' extinction." The following excerpt is from this discussion between members of Group A and the principal researcher during the "Consequences/effect wheel" activity.

Olga: I am not sure about whether this is a first order consequence.
John: I am not sure either. I think it's here though.
Researcher: You can read it carefully and decide then.
Olga: Hm, see there is this article about how whaling affects the ecosystem …
Researcher: Exactly.
Sergey: It says that whales are vital to the food chain.
John: It regulates the food flow of the ocean.
Researcher: How do they do that?
Olga: I can't find it.
John: Here, I know, "they consume a whopping 40 million krill".
Olga: Wow! So is this a first or second order consequence? I think it is
John: It is a first, right?
Sergey: Yes, I think so too.
Olga: Okay, let's add it then.

The above sequential activity covering two sessions involving both conceptualizing by naming and conceptualizing by theory, supported students to structure their thinking and research strategically, through developing their viewpoints and individual meaning making. The collaborative learning structures ensured that all students were able to have input, ensuring that they were actively involved in the discussion and this was a way to open up learning to diversity. 'Weaving' (Luke et al., 2003) between back and forth in terms of experiencing the known and conceptualizing helped students reach the learning goals. Drawing on students' prior knowledge first, and building on it to deepen students' conceptualizations, is a meaningful way to address diversity (Savva, 2016b). In particular, "overt instruction" in multiliteracies pedagogy, goes beyond assimilation and teacher-centered transmission (Mills, 2006). The students were thus able to have access first, and participate secondly, in the activities, regardless of their knowledge level, using their own meaning making resources.

Analytical Learning

In the analytical knowledge processes, students in Group A explored a range of texts from the museum visit, including labels, videos, pictures, media articles and essays. Students engaged in activities such as the "Juxtaposition", where they compared and contrasted two museum texts in terms of content, structure and language features (*analyzing functionally*). Taking a stance on the use or not of labels in museums, they stood in a corner of the room during the "Four corners" activity (*analyzing critically*). The following excerpt is from this discussion between members of Group A and the principal researcher during the "Juxtaposition" activity.

Researcher: How is reading this essay different from watching the video with the text?
Olga: There is movement in the video.
Sergey: And you see more things happening.
Researcher: Yes!
John: You get more information from a video.
Sergey: People talk and you hear sounds.
Olga: Yeah … It is more interesting. John: You also understand the meaning easier because you see and hear and all, the tone is different. So I think this is why they chose to use this at the museum.

Analyzing functionally through juxtaposing primary and secondary sources, novel and film versions enabled this group of students to focus on the language and visual features of these texts. The significance of this process, lays in preparing students for creating their own texts in "Applying." Concurrently, *analyzing functionally* also enabled the students to understand how the curators of the exhibition decided to use each text and position visitors in particular ways in *analyzing critically*, gradually involving them in a variety of cultural knowledge and perspectives. This was evident in the "Four Corners" activity. Each group decided on whether to go for "agree," "strongly agree," "disagree," "strongly disagree." Each corner's group discussed the statement and developed a collective response to be shared and debated. The excerpt that follows is from Group A's discussion while trying to prepare their argument.

John: So, we are claiming labels are important in museums …
Researcher: Why is that?
Olga: There are labels in other places and are important there. Like a bus stop.
Researcher: Okay right, that's called a sign but it is similar.
John: There are people who don't know what an object is about. And the museum has to teach them.
Olga: You explain things with writing.

Sergey: And it is sometimes interesting to know about an object's story.
John: Yeah, when something happened and what era does it belong.
Olga: So labels are important in a museum.

Students, as shown above, asked questions about whose interests are served in using labels in a museum and how they can be of use. In this sense, they were empowered to critique the approach of some curators to leave out labeling from exhibitions. Students indicated signs of agency, not only as critical readers in and beyond school, but also in developing their own texts, which could suggest they acted as learner transformers (Comber & Kamler, 2005; Gee, 2000). Importantly, the critical framing stage which adheres to "analyzing," according to Cloonan (2007, p. 4), leads to students detachment from what they have learned, and develop critique of the learning already gained, through situated practice (experiential) and overt instruction (conceptual). In this way, the analysis builds on the experiential and the conceptual. Students in Group A, were able to progress from superficial knowledge, to deeper understanding, by denaturalizing and assessing learning "in relation to the historical, social, cultural, political, ideological, and value-centred relations of particular systems of knowledge and social practice" (New London Group, 2000, p. 34). For example, John was able to see how some people would appreciate information in labels since they might not have sufficient knowledge about an object. He also appreciated that other children of his age from other cultures might also like to read the labels in a museum like himself.

Applied Learning

The final transformative stage within the LMP process involved "applied" learning. Students moved to a level of being able to create and become knowledge producers. This was achieved using a range of modes and media, which in turn catered for a variety of "learning styles" or multiple intelligences (Gardner, 1999), including the visual, auditory, linguistic, spatial, and gestural (Kalantzis & Cope, 2005, p. 239). In particular the "Curator for a day" activity, during the museum educational visit, and the presentation of their work for the Living Museum during the "Museum Day," are evidence of Group A's collaborative work and advancement of literacy repertoires.

The following is an excerpt of the "Curator for a day" activity, while students worked individually on developing a room based on a hypothetical scenario they had previously thought of in their Groups during the museum visit taking inspiration from an exhibited work.

Sergey: I think the background is wrong.
Olga: I am not sure. We should ask the teacher.
John: I like the colours, and you have placed the objects in a nice way. It looks real …
Sergey: Do you prefer that I add one more chair here?

John: No, it looks great as it is. Mine is not as good, it's overwhelming. I will figure it out.

Olga (*while gluing*): I love this. It's probably the best activity so far!

It was evident from the three focal students' performance in *applying appropriately*, that, despite their difference in abilities and subjectivities, the activities suggested an improved performance. Looking at Olga's collage, it was evident that she had produced a high quality work, based on the background, the colors, and arrangement of objects. She also understood the layout and the genre. She was interested in design and fashion, which was what she was passionate about. She was detailed in every aspect of placing the objects and resulted in a realistic scene. John, on the other hand, was not as detail prone, and his creation was somewhat confusing due to the choice of colors and background. It was clear that he was keen to incorporate different elements in his collage, yet he found it challenging to create the final piece of work. Finally, Sergey's collage was simple, yet with a good balance as far as the background, the colors, and arrangement of objects.

During the process of constructing their room, John encouraged Sergey, by stating how well he was doing, and being overall more apt to lead the group, coordinating the other two to achieve the planned objectives. Sergey was timid, yet prompted by his classmates, he was able to complete the task as an autonomous and active learner. What was profound in this activity, is how Olga showed a much more positive attitude towards the lesson, unlike her usual self during the first couple of weeks of the LMP when she seemed disinterested to participate. This was attributed to her feeling more competence, and having increased self-esteem due to her personal interest in the task.

The final piece of the puzzle of the intervention, included the presentation of each group's work during the "Museum Day." Group A presented their work by having John introduce the museum wing for aquatic biologists, and discussing how his group went about to think of what content to include in their museum and how to present it and why in terms of print and multimodal ways of communication. Olga presented more specific information about how the three set up the fast facts page and interview with an aquatic biologist.

What was evident from this group's PowerPoint presentation and digital multiliteracy practices observed overall during the LMP, is that the use of the knowledge processes benefited students in terms of agency—simply put this means giving students voice through guided activities. Scaffolding students' agency through the knowledge processes, resulted in higher levels of autonomy, indicated improved levels of ownership of their learning and suggested empowered subjectivities, as confirmed by students' and teachers' reflective interviews. It is crucial that this type of student agency is embedded in teaching and learning. Importantly, what the final presentation pointed out is, that these students were able to gain a deeper understanding on how and when to apply the strategies attained in different contexts, rather than reducing them to "school activities" or "timefillers" (Anstey & Bull, 2004, p. 160).

Conclusions

The main characteristics of the museum–school partnership of the research acting as an emergent multiliteracy practice are seen below (Fig. 12.3). In some cases, the collaborative activities suggested the LMP and in particular digitally mediated activities through the WebQuest achieved the impact of promoting a positive learning environment where the average and weak students gained self-esteem. This in turn facilitated students' engagement with different activities in particular in multimodal tasks. Kellough and Kellough (2008) make the point that teachers should use effective teaching approaches which can lead to a positive classroom environment. It was evident that the various activities in the LMP paved the way for students to research ideas, act creatively, and perform better using the five aspects of multiliteracies through the computer as a medium and to later present their work.

Different aspects of the LMP contributed to students' collaborative and group work; problem solving and thinking; analyzing and research skills; print and multimodal literacy; speaking and listening; and critical thinking and reflective practice. Another important aspect of the instructional framework that contributed to expanding students' repertoires was engagement with multimodal texts across all stages of the LMP. Students were motivated by the use of digital texts yet more importantly the different modalities catered for their variant learning styles and low linguistic performance. Baker (2010, p. 67) states that "meaning expressed in one mode cannot be directly and completely translated into another." The use of verbal modes

Fig. 12.3 Elements of a museum–school partnership as an emergent multiliteracy practice

(reading, writing, listening, and speaking) as well as nonverbal modes (visual, embodied, audio, gestural, tactile, and spatial) are an integral part of multiliteracies pedagogy and in particular museum with its unique nature has a lot to contribute towards addressing multimodalities.

What remains to be seen is the extent to which these approaches which positively influenced student learning and affective outcomes can be adopted in the long run in a more systematic way in schools and be sustainable and feasible within routine classroom practice. It is proposed that a longitudinal view of the museum–school partnership to be sustainable is necessary and for students' learning outcomes to continue to improve. Nevertheless, students' improved engagement with the multiliteracy activities and positive attitudes are a good sign of possible success in the future of implementing the Museum Multiliteracies Practice as a framework for undertaking successful museum–school partnerships. The requirements, of course, are for the partnership to comply with the principles and characteristics described earlier as prerequisite to maintain the innovation.

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Chapter 13
How the Materiality of Mobile Video Chats Shapes Emergent Language Learning Practices in Early Childhood

Christian Waldmann and Kirk P. H. Sullivan

Abstract Language learning practices are shaped by their material conditions. Using an action research case study intervention, this chapter shows how the introduction of mobile video chats for children learning a home language creates the material conditions for language engagement and participation practice to emerge that encourage the learning of the home language in additional contexts. The mobile video chat's concomitant role in enacting change in the children's home language learning practices facilitates home language learning in authentic and meaningful interactions. The material characteristics of the microphone, the web-camera, the loudspeaker, Skype and the portability of the tablet together with the material characteristics of their physical environment have the potential to enact change in children's additional language learning through listening, seeing, speaking, moving, and showing in virtual interaction with a grandparent as adult conversational partner.

Introduction

The purpose of this chapter is to explore the emergence of a language learning practice in early childhood made possible and shaped by the material conditions of mobile video chats. More precisely, we ask whether the use of mobile video chats in the home and the associated changes in the material conditions of children's physical environment influence language learning opportunities and interactions for early language learners of languages not widely spoken outside of their homes. We frame our study within action research aiming to "bring about critically informed changes in practice" (Cornwell, 1999, p. 5). Building on the premise that the use of

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mobile video chats creates conditions for language engagement and participation for early language learners, we show that a communication and participatory practice emerges with the use of mobile video chats. We focus on how mobile video chats make possible meaningful language learning opportunities and language interactions, engagement and participation in authentic milieu with relatives in ways that would not be possible without mobile video chats such as Skype. We argue that the use of mobile video chats at home transforms children's attitudes to their other linguistic community, makes learning the other language meaningful, and helps children develop and maintain an emotional relationship with others and with the language the child is learning.

Language Learning and Mobile Video Chats

Language skills from birth to adulthood are acquired through social participation in linguistic communities. The learner wants to become a participant in a linguistic community and is emotionally driven, making use of the materiality of video, images, sound, and movement together with the materiality of the physical environment when interacting with meaningful members of the community of practice (Wenger, 1998). Ideally, more knowledgeable meaningful members of the community of practice—for example, peers, teachers, and other adults—scaffold the language learner's communication in socially embedded interactions and support the learner's development for independently using and understanding oral language (e.g., Vygotsky, 1986). Such scaffolding and support are prerequisites for language development (Justice & Ezell, 1999; Justice & Kaderavek, 2002).

Scaffolding is dependent on, among other things, the material conditions of the physical environment, the opportunities provided for language learning and the interactions (Dockrell, Bakopoulou, Law, Spencer, & Lindsay, 2015). The physical environment provides the infrastructure that shapes the emergence of authentic and meaningful language learning opportunities and interactions. Children need regular opportunities for language exposure and use, and they need to engage in language exchanges and interactions that support their receptive and expressive language abilities so that they feel part of the language community they are emotionally attached to and wish to fully enter. The quantity, linguistic quality, and meaningfulness of children's language learning opportunities and interactions predict their future language proficiency. The amount of language exposure and verbal communication shapes children's word comprehension, vocabulary size, and complex syntax with differences in children's language growth and ability emerging early (Marchman & Fernald, 2008; Vasilyeva, Waterfall, & Huttenlocher, 2008). The variety of words used by parents/guardians, and their ability to respond to children's efforts to talk support language learning through preschool (Hoff, 2006). For example, Huttenlocher, Vasilyeva, Cymerman, and Levine (2002) and Dickinson and Porche (2011) found that the density of sophisticated vocabulary, complex syntax, and interactive conversation facilitates children's language learning possibilities.

Children whose participation in authentic and meaningful interactions is limited may face difficulties in developing certain language skills and achieving adult-like language proficiency. This is generally not the case when children acquire languages spoken by both parents/guardians in the family as well as in their community, hereafter referred to as community languages. However, many children are exposed to one or several languages in addition to their community language(s), for example the child exposed to Portuguese in a Swedish-speaking community. In this chapter we refer to such additional languages that are spoken within the family, at times by only one parent/guardian, and learned by children in isolation from the community in which these languages are spoken, as home languages.

As languages spoken in the community have a wider applicability and use than home languages, children exposed to both community and home languages receive a larger amount of and qualitatively more versatile opportunities to participate in authentic and meaningful interactions in their community languages. Opportunities for exposure to and use of the home languages are often limited to interactions within the family, and in some cases even to interactions with the one parent/guardian speaking the home language(s). In such cases children may not receive enough exposure and meaningful opportunities to engage in social interactions and practice and develop certain skills in the home languages. In particular, language use confined to specific contexts within the family may result in gaps in linguistic as well as socio-pragmatic skills. For example, as bilingual children use the community languages in conversations with peers and at preschool, they may face difficulties in developing the appropriate lexical skills and language routines in their home languages (e.g., for solving disagreements with parents and home-language peers).

Bilingual children learning a home language require special support to achieve highly functional language. Young language learners most readily achieve language proficiency when conversations include opportunities for language learning with adults close to them in safe environments (Philp, Oliver, & Mackey, 2008). Children and adults from the same family coming together to engage in social activities and interactions form a community of practice in the sense of Wenger (1998). The child and the adult share and are committed to a domain of interest defined by the emotional connection between the child and the other members of the child's family. The child and the adult pursue their shared interests as a community through engagement in joint activities and interactions, thereby facilitating mutual (incidental) learning. By regularly engaging in sustained interactions, the child and the adult continually develop a shared practice of stories, experiences, tools, concepts, actions, artifacts etc. that characterize the learning of their community. Creating such communities of practice for home language learners can be challenging. However, the materiality of mobile video chats has the potential to shape conditions for participation in emergent meaningful language practices, thereby facilitating bilingual children's exposure to and use of home languages.

The material conditions of mobile devices (e.g., tablets) and video chats (e.g., Skype and FaceTime) create great potential for supporting learning and development (Melhuish & Falloon, 2010). Affordances that facilitate the creation of opportunities for young home language learners to participate in authentic and meaningful social interactions include the portability of the device, the touch screen technology, the access to situated and personalized language learning experiences, the virtual access to social interactions and the multimodality of the device.

Mobile devices are ideal learning devices as their size and weight allow them to be carried around easily. Their portability and tactile nature embodies the technology and facilitates unconscious application to tasks at hand, which means that mobile devices can be naturally integrated into learning experiences and social interactions. Kukulska-Hulme, Lee, and Norris (2017) point out that mobile devices "are uniquely suited to supporting language learning on an ongoing basis, in a range of settings, according to a person's ability and adapted to their needs (Gu, Gu, & Laffey, 2011; Hsu, Hwang, & Chang, 2013; Ng, Lui, & Wong, 2015)" (p. 217). The power, portability and functionality of mobile devices allow ubiquitous language learning; learners can engage in language learning whenever and wherever they want. Mobile devices, therefore, can facilitate the motivation, creativity and engagement of the learner and support situated personalized language learning (e.g., Burden, Hopkins, Male, Martin, & Trala, 2012; Jahnke & Kumar, 2014).

These specific material conditions make such devices suitable as learning tools for young children. In fact, children as young as 2 years quickly learn to use mobile devices independently and confidently, and they use them freely to play and explore (Chiong & Shuler, 2010; Couse & Chen, 2010; Michael Cohen Group & U.S. Department of Education, 2011). Applications (e.g., gaming apps, creating apps, and literacy apps) on mobile devices have also shown great potential for supporting young (3–7-year-old) children's vocabulary and phonological development (Chiong & Shuler, 2010), as well as the development of literacy skills (e.g., Cubelic & Larwin, 2014; Neumann, 2014).

The use of video chats provides conditions for language learning. Video chats afford virtual access to multimodal opportunities to participate in authentic interactions with people that are close to us in a way that is similar to face-to-face interactions. That is, video chats create the conditions that allow language learning to occur in authentic milieus with people that matter. For example, Roseberry, Hirsh-Pasek, and Golinkoff (2014) found that video chats support language learning in monolingual toddlers: "Socially contingent interactions, like those in video chats and live interactions, provided toddlers with sufficient social information to learn language" (p. 968). Mundane video chats are also actively used by families to keep in contact with distant relatives in order to support the intergenerational transmission of home languages to their children (e.g., Braun & Cline, 2014; Mejía, 2015). The material characteristics of virtual access that video chats provide creates opportunities to interact with native speaking relatives in authentic and meaningful contexts; these contexts have been shown to be crucial for the development of home languages (e.g., Borland, 2006; Szecsi & Szilagyi, 2012). For example, Szecsi and Szilagyi (2012) found that the use of video chats on Skype facilitated young (2–8 years) home language learners' vocabulary acquisition as well as cultural awareness and identity. The study also concluded that communication through Skype chats have the potential to motivate children to use the home language. Such increased motivation will result in home language children making use of existing language learning opportunities and developing them into language learning interactions.

Turning specifically to the material conditions and affordances of mobile devices and video chats, it is likely that these characteristics will facilitate the emergence of a community of practice that supports early home language learners' by providing authentic language learning opportunities and meaningful language interactions.

This chapter presents a study that focuses on how mobile video chats can be used to support language development in young bilingual children learning home languages through informal social interactions. More precisely, by exploring the use of mobile video chats in the home we study how a change in the material conditions of children's physical environment influences the language learning opportunities and interactions.

Methodology

By using a collaborative parent-researcher case study (Stake, 1995) in which we used action research we were able to study the use of mobile video chats to support home language learning in the home environment. Action research provides a methodological framework to study the language learning practices that emerge by introducing mobile video chats from a holistic perspective (Stringer, 2008). At all times the Swedish Ethical Review Act (SFS, 2003:460), and the Swedish Research Council's Ethics Guidelines (Hermerén, 2011) were followed.

A convenience sample of two bilingual children living in Sweden, a 3-year-old and a 6-year-old, participated in the study. In addition to the community language Swedish, both children were learning English as a home language. Generally, one parent conversed in Swedish with the children and the other parent conversed in English. Growing up in a Swedish-speaking society and enrolled in Swedish-speaking (pre)schools, Swedish tended to be the stronger more dominant language for both children. However, the children regularly engaged in conversations through Skype (video) chats with their monolingual English-speaking relatives. As more competent conversational partners with close familial ties to the children, we saw these relatives as naturally scaffolding language input (McManis & Gunnewig, 2012) in ways that non-familiar adults would not be able to do (Borland, 2006). Further, this naturalistic family setting allows for observations of spontaneous oral language activities.

Over a period of 5 weeks, we introduced mobile video chats with Skype to observe how the two children interacted with their geographically distant relatives and how the mobile video chat shaped emergent home language learning practices. When the study began, both children were familiar with Skype and mobile devices, but the children had only used Skype on laptops.

In order to maintain the authenticity of the social interactions and not change the home environment by introducing unfamiliar adults, the observations were conducted by one of the parents who is also a trained researcher. This research thus has both etic and emic perspectives; our experimental design is etic and our observation emic. Research of an ethnographic nature is as Cousin (2009) states "best positioned simultaneously as an insider *and* an outsider" (p. 112).

The observations focused on how the introduction of mobile video chats created language learning opportunities and interactions. During the observations, the parent-researcher had the advance of knowing the materiality of the language learning situation before the introduction of the mobile video chat, and was reflexive, that is "sensitive to the nature of, and conditions governing, their own participation as a part of their developing understanding" (Davies, 1999, p. 73).

The children were observed on average twice a week for 5 weeks (in total 10 times) interacting with their monolingual English-speaking relatives. The mobile video chats lasted for between 10 and 30 min. Each observation started with a parent placing a Skype call. As soon as the Skype connection had been established, the children engaged in conversations with the relatives and were free to use the mobile device, play, and create their own language learning opportunities and interactions. As we were interested in how the materiality of mobile video chats shapes emergent language learning practices, we decided not to guide the way the children used the affordances of the technology, and to allow the materiality to organically emerge.

During the conversations, the parent-researcher observed how the children embedded the mobile video chat in natural play situations noting the ways in which opportunities for meaningful interactions were created. At all times the parent-researcher aimed to have reflexive distance. The notes were thematically analyzed and classified as examples of language learning opportunities and/or interactions. Both authors analyzed and classified the observational notes to strengthen the reflexivity of the analysis. For example, if the child takes the clothes of their doll, walks to the cupboard to select new clothes and then puts the new clothes on the doll, the interaction could include a discussion of what new clothes to choose, why these clothes are chosen and what the doll would do when changed. This act would require the child to take the mobile device around to keep the conversation active and to show using the camera what clothes were available. This play situation was classified as a language learning opportunity and interaction. If an opportunity did not develop into an interaction, it was classified as only an opportunity.

As our approach is qualitative we are interested in the ways in which mobile video chats enable children participation in home language learning opportunities and interactions rather than how often particular opportunities and interactions occur, or whether mobile video chats are superior, or otherwise, in supporting home language learning opportunities and interactions than other approaches. In the next section, we present and discuss examples of how the mobile video chats that the children were engaged in created language learning opportunities and interactions, thereby facilitating the children's exposure to and use of the home language. Finally, we reflect on how material conditions define the type of learning practices in which young children are able to engage and participate.

Findings

Language Learning Opportunities: An Emergent Language Learning Practice in the Home

Children need opportunities to engage in conversations and listen to and practice the languages that they are learning. We found that mobile video chats provided novel opportunities for participation and thereby for language learning. By novel we mean the mobile video chats facilitated language learning opportunities with the home language speaker that had not been observed by the parents earlier. The children were able to move around and embed the video chats in the natural play context, including rapid changes in play focus. The children would leave one play activity, and carry the mobile device to the next. For example, in one video chat the 3-year-old is walking around interacting with the English-speaking grandmother and showing her a paper butterfly. The child then decides to show grandmother a dance, places the mobile device on the couch, adjusts it so that the grandmother can see the dance, and performs the dance.

The flexibility of place is positive for early language learners. Language learning opportunities created by the flexibility of place included sharing what was on television, displaying newly built Lego buildings, and introducing the Skype-partner to visiting friends and callers, even those who did not understand English and were thus unable to participate in the conversation. We found that the 3-year-old was as able as the 6-year-old to use the flexibility of place afforded by the tablet to create language learning opportunities of personal interest. That is, children are able to influence the language learning opportunities and conversational topics in a similar way to face-to-face interactions. When the children wanted to show things to the relative when using mobile video chats, the children were about to "bring" their conversational partner with them in the same way as if this partner had been visiting in person. In fact, perhaps even more easily as the conversational partner has fewer opportunities to delimit where the child goes than when physically present, and definitely more easily than for earlier generations limited to traditional telephones and stationary computers.

Previous studies have shown that 2–6-year-old children quickly and with only little guidance develop proficiency in using mobile devices productively for activities such as drawing, writing and displaying media content (Chiong & Shuler, 2010; Couse & Chen, 2010; Geist, 2012). Our study focused on a more complex activity (i.e., mobile video chats) involving a combination of technological and interactive challenges. Children need not only to master the multimodality of the device (i.e., the audio and video technology), but also to be able to uphold a conversation with a person on the screen and involve this person in play contexts. Although the parents in our study were not to get involved in or guide the children in their use of the tablets unless the children asked, we observed the need for the parents to support and scaffold the children's use of the technology in order to facilitate the creation of language learning opportunities, in particular for the younger child. The 6-year-old was able to use the tablet independently to create language learning opportunities, whereas the 3-year-old was not as confident in using the technology independently. For example, in one video chat, the younger child tried to show their grandmother a paper butterfly, but did not seem to fully understand where to hold the butterfly in order for grandmother to see it. Instead of holding it in front of the camera, the child placed it on the touch screen moving it towards the camera asking “Grandma, where is the butterfly?” Due to an incorrect use of the technology, this language learning opportunity was lost as the grandmother could not see the butterfly and therefore could not develop a conversation about the butterfly. This lost language learning opportunity may have been inspired by the older sibling who when feeling mischievous often “hid” the thing s/he had just shown on the mobile video chat and asked where it was. The 6-year-old knew that the conversational partner was unable to know where it was; the parents thought it likely that the 3-year-old was copying the older sibling, but that less developed understanding of the technology resulted in the loss of a language learning opportunity.

Our study suggests that the material conditions of mobile video chats such as portability, multimodality and access to situated, authentic, and personalized experiences creates authentic language learning opportunities, allowing an emergent language learning practice to develop in the home. With the tablet, the children stayed continuously in contact and interacted with the relative, even when running around showing different things. The use of the mobile device provided continuity in the conversations by affording language learning opportunities at the same time as it facilitated and supported the children’s interest in interacting with the home language relative. It created conditions for participation and engagement in the other linguistic community to which they also belong.

Language Learning Interactions: Material Conditions for Participation and Engagement

For a language learning opportunity to support language development, it needs to develop into an interaction in which the language learner can participate and engage in order to practice his/her receptive and expressive language skills in various authentic contexts scaffolded by a more competent speaker. This is not unique for mobile video chats but true for all language learning situations, whether live or virtual. Simple, everyday acts in the home are language learning opportunities that can be developed into language learning interactions, and many of these are for many reasons not developed. Hence, we do not see it as an issue, per se, that mobile video chat language learning opportunities are missed and do not develop into language learning interactions.

Like Roseberry et al. (2014) we observed that language learning opportunities led to language learning interactions when adult Skype partners are contingent, and develop conversations around the opportunities the child provides. For example, by bringing their tablets to their bedrooms to show the relative pictures they had drawn at (pre)school, children provided language learning opportunities; yet, these opportunities only became language learning interactions when the relative created longer conversations around these pictures that the child engaged in. Paralleling face-to-face conversation, we found that simple comments (e.g., "How nice!") and yes/no questions (e.g., "Did you draw that yourself?"), led to lost language learning opportunities. However, when the adult Skype partner developed conversations around the pictures, for example by asking open-ended questions that extends the children's thinking (such as "how," "why," and "what" questions) or elaborated on children's utterances, for example by adding syntactic or semantic information, the opportunities developed into language learning interactions that support and scaffold the language learner by providing a much richer and versatile exposure to the home language and by facilitating more challenging/complex language practices.

Although the 3-year-old was as able as the 6-year-old to create language learning opportunities of personal interest, the opportunities provided by the younger child were more likely to be lost if the adult Skype-partner failed to create conversations. Whereas the 6-year-old could develop an opportunity into a language learning interaction by him/herself, the 3-year-old was less able to do so, reflecting the children's cognitive and linguistic development.

We also observed that the children lost interest in participating and engaging in interactions with the relative if s/he repeatedly failed to use the opportunities provided by the children to create conversations. Adults impact positively on children's language abilities as they have the ability to provide interactive conversations using a more sophisticated vocabulary and complex syntax, coupled with an ability to respond to children's efforts to talk, and to extend and clarify what they say (Dickinson & Porche, 2011; Hoff, 2006; Huttenlocher et al., 2002). In our study, the relatives usually successfully created authentic language learning interactions. The conversations developed from objects into broader topics. For example, a picture drawn at preschool was used to discuss the picture, the friends in the picture, the day at preschool and what would be happening at the weekend. The richness of the conversational development was lost in the observational note taking, and we suggest that a future study video-tapes the interactions to allow linguistic, conversational, discourse, and multimodal analyses.

In sum, both adult and child interlocutors spontaneously instigated virtual language learning interactions using the language learning opportunities afforded by the material conditions of mobile video chats. The video, sound, and virtuality combined with mobility create a condition that allows access to social interactions that are similar in form and spatial flexibility to physical face-to-face interactions. These material conditions provided the children with challenging language learning practices based in authentic language participation and engagement.

Discussion

This study illustrates that using Skype-based video chats on mobile devices opens up language learning opportunities and interactions for young language learners. This suggests that mobile video chats have potential as tools for supporting language development as they can support conversations that provide young children with a rich exposure to language, and opportunities and interactions to use and practice language in various authentic and meaningful contexts. Cerratto Pargman, Knutsson, and Karlström (2015) argued how little attention has been paid to the material properties of new technology, and write as follows: "The sociomaterial nature of the technology and its concomitant role in enacting change in our learning practices has so far been overlooked" (p. 308), and that action and learning are "bound by the material characteristics of the artifacts in use" (p. 308).

Hence, at one level we argue that using the mobile video chat (the new technology) to language support facilitates home language learning in authentic and meaningful interactions and allows the child to access the advantages of functional bilingualism as well as additional advantages of bilingualism that potentially include protection from the cognitive function decline that accompanies the onset of Alzheimer's disease (e.g., Bialystok, Craik, & Luk, 2012; Craik, Bialystok, & Freedman, 2010; Perani et al., 2017; Schweizer, Ware, Fischer, Craik, & Bialystok, 2012; Stern, 2012), maintenance of memory skills in old age (e.g., Schroeder & Marian, 2012), school grade improvement—bilinguals have been shown to be better at focusing on relevant aspects of their environment and tasks they are undertaking, at switching between tasks (Prior & MacWhinney, 2010), at processing linguistic information in the learning process (Bartolotti & Marian, 2012; Kaushanskaya & Marian, 2009), and improved metalinguistic and phonological awareness that are core aspects of reading and writing development (Apel & Apel, 2011; Melby-Lervåg, Halaas Lyster, & Hulme, 2012; Sénéchal, 2014).

Yet, at another level, we need to consider which material conditions afforded the participation and engagement to make an emergent language learning practice in the home that gives children access to the social and cognitive advantages of bilingualism possible. That is, the material conditions are not a "black box" piece of new technology, but rather material properties of the mobile video chat across differences that support participation, engagement and learning. Further, these material characteristics may need supporting in order to facilitate the child's participation and engagement in the virtual interaction. For example, as in face-to-face situations, the younger the child, the greater the responsibility the adult conversational partner has to develop conversations around the opportunities that the child provides. In this study, we limited the impact of material characteristics by not encouraging the adult to create language learning opportunities, but rather primarily expecting the child to create these opportunities. As home language learners may face difficulties developing certain pragmatic skills and language routines it is probable that if children decide which opportunities to create then they may not broaden their pragmatic skills and language routine as the opportunities for practicing these will remain limited. This demonstrates that the material characteristics of the "black box" need to be understood for them "to enact change in learning practices" (Cerratto Pargman et al., 2015).

The children in our study were motivated to learn English, and accepted the challenge to use their home language to communicate in additional authentic settings and activities so that they could develop their relationship with their grandparent—necessity, motivation and enjoyment interacted with the material characteristics of the mobile video chat. These children were able to listen to their grandparent's voice that afforded both additional home language input and the development of an emotional link to their grandparent, they were able to see their grandparent and to know that they were being seen, they were able to speak and be heard by their grandparent, they were able to move the conversation in place that allowed the creation of a "real" visit by their grandparent, and they were able to show important elements of their lives in a natural and spontaneous ways. The material characteristics of the microphone, the web-camera, the loudspeaker, Skype, and the portability of the tablet together with the material characteristics of their physical environment and the grandparent as adult conversational partner enacted change in their additional language learning through listening, seeing, speaking, moving, and showing.

In sum, the use of video chat on mobile devices with their associated material characteristics together with those of the physical environment can support early language learning, and this emergent practice has the potential to configure and transform language learning and teaching practices in preschool and primary school, as effectively as we have demonstrated in our case study that it transformed home language learning for the young bilingual children by facilitating informal social interactions with a native adult speaker. We suggest that future research could usefully employ evidence-based observation protocols (cf. Dockrell et al., 2015; Waldmann & Sullivan, 2017) to examine how the use of mobile video chats creates language learning opportunities and interactions in formal classroom settings.

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Chapter 14
Sociomaterial Configurations and Resources Supporting Observations in Outdoor Learning: Results from Multiple Iterations of the Tree Investigator Project

Heather Toomey Zimmerman and Susan M. Land

Abstract Guided by a sociocultural framework that considers the intersection of people, tools, and settings, we describe research and development aims of a mobile app and the pedagogy supporting its use in outdoor learning. Our research investigates sociomaterial configurations that can influence youths' observational practices with tablet-mediated collaborative knowledge-building activities. Our work includes field tests with hundreds of learners and seven design-based research (DBR) iterations with 185 consented subjects. We report findings across these iterations of research, which are related to (1) the material conditions of the technology design and redevelopment and (2) the evolving theoretical framework focused on the concepts of scientific talk and practice. This chapter describes how we conducted our iterations of research leading to our trialogical approach to learning. As such, we describe how the materiality of the outdoor setting influenced our work and how various sociomaterial configuration for learning emerged based on our research findings. Implications for tablet-supported collaborative learning and technologically enhanced informal learning are drawn in the conclusion of this chapter.

Introduction

Our work builds from the sociocultural approach for education (Cole, 1998; Vygotsky, 1980) to understand how tools, people, and contexts come together when learning. More specifically, we draw upon theories of sociomateriality (Orlikowski, 2007) that posit that learning and meaning-making rely on

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technologies, places/spaces, and natural and designed objects present in everyday life—or in our case, people learning together with tablet computers in outdoor settings. This perspective is apt for research and development efforts with mobile computing for two reasons. First, one main goal of our work is to engage youths and families in the intellectual work of scientists; as shown by Latour and Woolgar (2013, 2nd ed.), the intellectual work of scientists relies on sociomaterial practice. Second, scholars in education have made the argument that not only are work environments relying on social and material interactions but so too are learning environments—understanding how learners come to understand a concept, for instance, is best accomplished with the tools used to learn that concept (Ivarsson, Schoultz, & Säljö, 2002). Within this chapter, we elucidate how we manifest sociomateriality in our research and development work. The first part of the chapter, we discuss how sociomateriality influenced our design across multiple iterations of research. In the second part of the chapter, we discuss how our data analysis moved from a dialogical to a trialogical perspective to fully illuminate the sociomateriality within learning interactions.

Research and Design Partnership

To accomplish our tablet-supported learning research and development work, we partnered with two outdoor learning centers, the Arboretum at Penn State and Shaver's Creek Environmental Center, to integrate tablet technology into youths' and families' science learning activities. Our work aimed to take a ubiquitous tool, a mobile phone or small computer tablet, and transform it into a learning resource that supported the creation of digital artifacts in the outdoors. Across our 6-year partnership, we designed learning experiences that met the rigors of the discipline of biology by engaging youths in collaborative sense-making around evidence they observed on nature trails. The trail-based learning activities needed to be educative and also fun—in order to reflect people's recreational goals for their out-of-school time. As such, we designed a mobile app and associated pedagogy for two related scenarios of use: (a) elementary-aged youth and their parents during family time (weekends, vacation days) and (b) 9–12-year-old children who signed up for a summer camp as part of their normal daycare or leisure activities. Both families and summer camp learners used the app during recreational time as they walked outdoor trails, exploring water and land habitats, and seeking serendipitous exposure to plants, animals, and nonliving features of the local ecosystem. We have used the Tree Investigator (T.I.) materials with over 400 youths and adults in developmental scenarios including youth attending a 1-day Arboretum fieldtrip, family visits to the Arboretum, and hundreds of summer camp children at Shaver's Creek and the Arboretum.

Design-Based Research Iterations

Our formal research findings are derived from a series of studies with 185 consented individuals across seven research iterations. DBR iterations 1–3 (Land & Zimmerman, 2015; Zimmerman et al., 2014) were focused on development; these iterations involved smaller numbers of learners and focused on fine-tuning the design of the T.I. mobile app to be suitable for informal educational uses. Iteration 4 (Zimmerman, Land, & Jung, 2016) and iteration 5 were the largest data collections; these iterations of T.I. focused on pedagogies exploring various configurations of sociomaterial support that could best influence science learning and youths' interests in science. From iteration 4 and beyond, the T.I. app included an augmented reality (AR) browser, digital photography, digital artifact creation, and on-the-fly annotations of learner-collected digital photographs. Iterations 6 and 7 worked with a smaller number of learners and were student-led dissertation efforts to bring new theoretical approaches to the T.I. materials. Iteration 6 focused on creating an imaginative narrative account featuring a squirrel in a comic-book-like format (Seely, 2015) and iteration 7 (Choi, Land, & Zimmerman, 2018) focused on integrating problem-solving techniques into informal learning experiences. This chapter discusses most fully iterations 1–5 but brings in the work of our colleagues from the last two iterations to consider how varying sociomaterial resources can influence learning (Table 14.1).

Within this chapter, we use our research and development efforts related to the Tree Investigators app and pedagogy to illustrate two ideas. First, we discuss how sociomateriality can inform and influence design efforts to support everyday

Table 14.1 The iterations of *Tree Investigators* app and pedagogy

	Focus	Learners
Iteration 1	Exploration of trees' life, reproductive, and season cycles.	Families in a garden
Iteration 2	Exploration of the tree life cycle with a photo-task for articulation and reflection	Families in a garden and forest
Iteration 3	Exploration of the tree life cycle with Augmented Reality scaffolds and photo-task for articulation and reflection; annotations	Children on forested trails
Iteration 4	Exploration of the tree life cycle with Augmented Reality scaffolds for photo-task and observational practices and collaborative annotations of digital photographs	Children on forested trails
Iteration 5	Exploration of the tree life cycle with Augmented Reality scaffolds for photo-task, annotations, and observational practices with additional support for peer discussions	Children on forested trails
Iteration 6	Integrating story-telling narratives into exploration of the tree life cycle; incorporated graphic/comic elements	Children in a garden and on forested trails
Iteration 7	Supporting problem-solving and leadership moves of children within an identification of the three life cycle task	Children on forested trails

technologically-enhanced learning in the outdoors. We illustrate our team's early focus on place-based learning, which evolved into a fuller consideration of multiple sociomaterial resources and configurations within science learning interactions. Second, we discuss how our sociocultural theoretical framework evolved from a dialogical approach centered on learning conversations to a trialogical framework that considers more fully the role of learner-created digital artifacts as conversational partners. The trialogical framework not only more fully elucidated the sociomateriality of technologically enhanced learning, but it also allowed for us to realize our focus on science practices related to observational inquiry, which rely on instrumental and social components. Sociomateriality's influence in our designs and analyses of learning are discussed in full below.

Adopting Sociomaterial Perspectives *When Designing for* Technologically Enhanced Learning

Our perspective (Zimmerman & Land, 2014) on designing for mobile computing started with place-based approaches (Gruenewald, 2003; Smith, 2002)—especially for science learning (Lim & Calabrese Barton, 2005; Semken, 2005). To this, we added findings from informal technologically enhanced learning (Hsi, 2003; Lyons, 2009) for supporting heads-up, engaged collaborative technologies for museum settings; and from AR (Dunleavy & Dede, 2014) to digitally add layers of resources or perspectives to an object that allow people to use and create digital content via a mobile device. We sought to augment the natural world by adding digital media that enables access to non-visible information such as scientific perspectives, databases, or tools for capturing and sharing data (e.g., Chen, Kao, & Sheu, 2003; Land & Zimmerman, 2015; Rogers & Price, 2008).

Designing an Augmented Reality and Digital Photography App

Our design focuses on the affordances of tablet computers and other small mobiles for outdoor settings. Key within our effort was the idea that the design of an app for the outdoors was not a simple task—we needed to do more than bring existing perspectives on school-based or museum-based designs (from indoor settings) to outdoor learning centers. The nature centers' unique context of people learning within the materiality of outdoor settings was, and is, a driving factor in our design considerations. Understanding the sociomateriality of the learning interactions is relevant to technologically enhanced learning because some materials, defined as objects, bodies, technologies and settings, afford and constrain different actions (Fenwick, 2014) within a learning setting. For instance, people's experience in the outdoors is a sensory experience—with sights, smells, sounds, and textures that influence learning.

Given our project's focus on observational practices, we assert that learners' sensory experiences must be attended to within our design work to support engagement in the practices of science inquiry. As such, we prompted learners to touch trees' trunks, to look carefully at seeds, and to listen for key species in the area. In iteration 1, a naturalist worked with the app to prompt learners to look deeply at trees. In iteration 2, more of the prompts were distributed to the app with a photo-creation task. In iteration 3, we designed two phases of activity where the naturalist (and app) structured youths' experiences and observations, and then during the second phase, learners worked more independently. Our research (Land & Zimmerman, 2015) comparing learners' talk in iteration 1–3, found that learners were able to notice and describe the plant species that they were observing to each other in similar patterns regardless of the app/naturalist configuration (between 46% and 52% of the talk in all three iterations was perceptual). We interpret this finding to mean that the sociomaterial configurations of the learners, place, T.I. app, naturalist, and materials did not matter greatly for supporting basic science observation practices; all configurations that we employed were able to support people to observe basic tree traits. We discuss how these confirmations supported conceptual and sense-making talk below, where differences were observed.

In iteration 6 (Seely, 2015), we added a new technological configuration: a non-human agent was introduced, Nutty the Squirrel in a revised T.I. comic-book version app that was intended for a younger audience (ages 5–9). The T.I. app used Nutty and his narrative to suggest that the youths look deeply at the environment to assist Nutty to learn about trees (in order to find acorns). Seely reported that, in contrast to earlier iterations of the app, substantially more instances of affective talk were observed, likely due to the combination of the younger age of the participants and the comic-strip narrative of the pedagogical agent Nutty, who elicited playfulness from the children. In iteration 6, changing the sociomaterial configuration of the experience to include a narrative and a likeable comic-strip agent, led to a new pattern of talk and interaction that exemplified enjoyment, interest, and surprise.

We also designed our app for use by people engaging with a dynamic, temporally changing setting—leaves change over a year's time for broadleaf trees, pinecones appear on pines in annual or biennial cycles, and seeds and fruits are available at various points during the growing season. Across all iterations, we found that the setting influenced sociomaterial interaction among learners and technology. Specifically, the setting was influenced by weather and climate, which was often an unanticipated force that needed to be attended to in our design work and on-the-fly pedagogical choices. For instance, while we could run the study in light rain (with waterproof cases), much to the delight of the children in our study, sometimes the available light and temperature played a role in what animals and plants were available. The flora, fauna, and abiotic aspects of the environmental setting interacted with the technology in a way that influenced the effectiveness of our designs. Given our focus on trees, we sometimes needed to move learners off the intended trail and instead, we moved to a new location under the trees' cover to use the tablets in rain. However, the technology was more sensitive to changes in the settings; for instance, batteries and touch-screen performance in cold weather and with learners' gloved hands, provided a difficult barrier to address. Consequently, we limited the timing of the outdoor education program to spring through fall in our northeastern USA climate based on setting-technology interactions. The setting-technology interactions' influence on learning also meant that a human guide (naturalist, camp counselor, or other adult) needed to adapt their pedagogy or assist learners in unexpected ways.

Our views on sociomaterial interactions include that the learners' bodies were a valued material resource in learning situations (Nespor, 2013). As learners moved their body through the outdoor space using the T.I app, they controlled their focus based on their own excitement and curiosity, rather than on the informal educators' view of what was interesting This learner-centered approach has been important in our work with families, where we found families linger longer in their outdoor exploration when the object of their inquiry is a child's discovery, rather than something that the naturalist or guide pointed out (Zimmerman, McClain, & Crowl, 2013). While the T.I. educative programs start with a naturalist posing the question: *How do trees grow in the forest?*, as the program continued, the naturalist ceded much of the teaching to the app. To understand how trees grow, the app included text that encouraged learners to use their bodies to differentiate between a sapling and a mature tree. For instance, because the T.I. app was built to be used by children and/or families with children 11 years and under, we used youths' body references for size ("a seedling will be sized below your hips"). Given these references to body-oriented measurements in the app, children estimated the size of small trees using their body as a point of size reference. The app included text that encouraged learners to touch trees with their hands to make an estimate of the tree trunks' circumference. The text in the app asked them to place both of their hands around the trunk of a tree at their chest height to determine if the tree was a sapling (hands can touch if clutching a trunk of the tree) or mature tree (hands cannot touch at chest height). Through these text prompts, the app acted as a coach or peer to suggest how the learners' body could be used to differentiate between stages of the trees' life cycle.

Pedagogical View of Integrating an App into Out-of-School Time Learning

In addition to addressing issues of sociomateriality in our app's technology design, we also considered sociomaterial resources in our pedagogy for out-of-school time to integrate apps into outdoor learning centers. In iterations 1–3, the pedagogy included the naturalist asking the learners to work in small groups with one computer tablet (an iPad with an app). In iterations 4–7, the teaching support included additional supports for learners, in addition to the iPad app. Adding a new material resource arose because, from analyses in iterations 1–3, we found that when looking on the trails in peer groups, the young learner with the tablet was likely to wander away from other youths; or the partners without the tablet were likely to wander away from the person holding the mobile computer. Given that the tablet computer held the primary learning supports, this resulted in an interaction where at least one member of every group was exploring without the sociomaterial mediation provided by the T.I. app's learning technology. In iterations 4–7, we add a sociomaterial configuration for learners that included an artifact to support peer-interaction and intellectual ownership for learners not holding the iPad. The T.I. app was identical for iterations 4–5 and 7; however, the sociomaterial configurations were varied by the research team. In the later iterations, each child who did not hold the iPad was given a small, laminated card that provided information (an abbreviated summary of what included in the app, so that they still had access to information included in the app if separated from their partner) and an additional *intellectual role*. This role included that they were to double-check and discuss with their partner the tree specimen selected to be representative of each life cycle stage; we called this the "fact checker" and "evidence confirmer" role. This role-taking was manifest in our data when the person holding the intellectual card asked the person taking a picture of a tree specimen with the iPad for confirmation that the specimen had the characteristics of the life cycle stage as outlined by the app. Our work has shown that this additional intellectual role, when added to our pedagogy, fostered longer, deeper conversations between pairs and additional discussion of evidence and tree traits than the groups that did not have the intellectual role card.

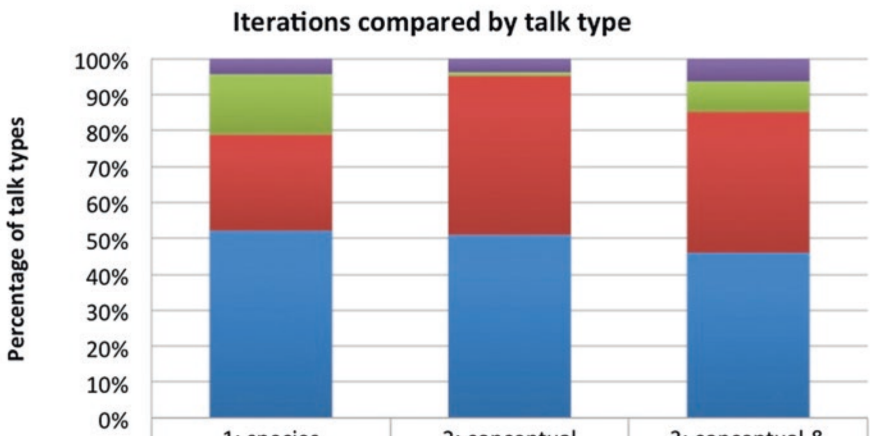
Adopting Sociomaterial Perspectives *When Analyzing* Technologically Enhanced Learning

Through our design iterations, as our technology evolved into a more complex, nuanced app to support science thinking in situ, we began to increasingly realize that our analysis needed to consider the influence of the app as a learning partner. Our original dialogical perspective from sociocultural theory allowed us to examine people's learning talk, but it did not fully account for the role of the app in supporting or hindering the learner. In the remainder of the chapter, we discuss how our research findings from our analyses of sociomaterial configurations influenced how we conceptualized tablet-supported learning.

In our research and development aims, we began our work with a sociocultural perspective on the importance of learning conversations (Allen, 2002; Leinhardt, Crowley, & Knutson, 2002), given the importance of sense-making talk (Bell, Lewenstein, Shouse, & Feder, 2009) in informal learning settings. These analyses of dialogue were important to our early work because the first three iterations of T.I. were focused on developing a flexible, collaborative mobile app that allowed learners to create, share, elaborate, and reflect on the plants (and animals) that they observed in their community gardens and nature trails. To do this work, we started our development efforts with an ethnographically inspired case study (Zimmerman et al., 2014). We started with families visiting an arboretum to understand what aspects of nature they wanted to share, what artifacts they wanted to create, what ideas they wanted to elaborate, and what science concepts they reflected upon.

From this work, we found evidence of the families discussing science topics together. Our analyses showed that the families discovered that there were science concepts in their community related to life cycles that families had questions about or in other words, wonderings that were unmet. We saw parents and children struggle to elaborate on some of what they were observing on plants, due to a lack of relevant scientifically-normative information. In iteration 2 (Zimmerman et al., 2014), we fine-tuned the app based on people's interests and on the struggles families faced. In iteration 3, we iteratively refined the photo-task to have scaffolds to make photo-documentation of the app more learner-centered, rather than naturalist-centered. Although these iterations were not designed to be experimental conditions, we (Land & Zimmerman, 2015) qualitatively compared the learners' talk from first three iterations in Fig. 14.1.

As stated above, all three versions of the app supported learners' ability to perceive and discuss basic observational features of the trees, as shown in the consistently high levels of perceptual talk across the iterations (Fig. 14.1). In iteration 1, we found the learners engaged in connecting talk (17%) and conceptual talk (27%) but we wanted to increase the conceptual talk to support engagement in explanation-building. In iteration 2 we added a conceptual organizer, and saw increased the conceptual talk (44%) but learners did not engage in the connecting talk needed to make sense of the content in light of their prior experiences (1%). In iteration 3 and



	1: species presentation	2: conceptual organizer	3: conceptual & annotation
Affective	4%	4%	6%
Connecting	17%	1%	8%
Conceptual	27%	44%	39%
Perceptual	52%	51%	46%

Fig. 14.1 The first three iterations of TI support learners' talk differentially, when analyzed with a learning talk framework from Allen (2002). Figure first appeared in Land & Zimmerman (2015)

beyond, the T.I. app included embedded prompts for discussion supports and collaborative annotation (within pairs or triads), building off prior work of collaborative annotation of video (Stevens & Martell, 2003). We found the collaborative annotation prompts were able to support learners' conceptual *and* connecting talk while on the nature trails (39% and 8% respectively). By having conceptual and connecting talk supported, the learners were able to make connections to theory, connect scientific objects and phenomenon on-site to prior experiences, and make inferences related to scientific concepts related to biology. Including both connecting talk and conceptual talk (Allen, 2002) are important in science learning because connecting talk represents sense-making and conceptual talk serves as a proxy for scientific thinking about the "big ideas" of biology needed for both further scientific study and civic engagement. We posit that given the number of groups walking through the forested areas, the app was able to provide just-in-time support to all learners whereas a naturalist could only work with one small group at a time.

A Trialogical Approach

As our work matured into iterations 3–5, we began to see how we needed a different theory — one that went beyond just considering the learners' conversations. Our data showed that the design of the technology influenced talk; to account for the sociomateriality of technology-enhanced learning by analyzing learning talk, we adopted a trialogical framework (Hakkarainen & Paavola, 2009) where we could analyze the role of the learner-created artifacts into the conversation. A trialogical approach considers the learners' artifacts as agentive in the learning conversations. This trialogical approach allowed us to analyze how the production of a photo-artifact influenced scientific sense-making in outdoor learning settings across sociomaterial configurations of learners, iPads, intellectual roles, and material resources. The trialogical perspective suggests that as people work together to create a knowledge artifact, the knowledge artifact is a both a learning process and a learning outcome (product) of the learners' interactions. In our research in out-of-school settings, we adopt the trialogical sociocultural perspective due to the importance of social meaning-making talk and creation in informal science learning (Bell et al., 2009).

Across the two iterations with the largest numbers of users (iterations 4 and 5), we compared two sociomaterial configurations. In iteration 4, children worked in dyads or triads with one iPad. In iteration 5, every child who did not have an iPad was given a small card that provided an additional intellectual role. In keeping with a design-based research perspective, the changes were derived from our analysis of the prior learning experiences as well as a desire to advance sociocultural theory that can support collaborative sense-making talk to support observation and explanation-building in youths' outofschool time.

Analyzing Science Learning Across the Groups

The trialogical framework allowed us to consider how 41 groups (consisting of 91 total children) engaged in the collaborative construction of digital photographic artifacts of tree life cycles at a nature center's summer camp. Overall the data from these two DBR iterations included: 91 matched preassesments and postassessments, video transcripts from 41 small group activities, and 41 learner-created, digital photographic artifacts. The small group work was transcribed and coded using a social sense-making scoring rubric to identify the extent to which learners collaboratively made accurate observations of trees and explained explicit connections to evidence or criteria that supported their identifications.

The unit of analysis was the sociomaterial interactions of each small group (rather than the individual child); the groups' scores represented the nature of collaborative sense-making while identifying five aspects of the tree lifecycle. Seven researchers coded one transcript together and then subsequently coded 16 of the 40 remaining small groups' transcripts separately on 12 possible pieces of evidence used to support claims about the identified stage of a tree's lifecycle, with each type of evidence being worth one point (12 points total possible). Interrater reliability was achieved at 90% accuracy for these 16 transcripts (representing 40% of the data). One researcher went ahead and coded the rest using the coding guide, which focused on the small groups' sociomaterial scientific practice of observation and coordinating evidence with explanations. In our coding guide, we include body interactions with plant materials, discourse, use of tools, and conversations with the youths' created artifact to realize the trialogical approach to learning.

Differences were shown in the sense-making scores between the two iterations, each featuring a different sociomaterial configuration. Our research found that the learners were able to discuss more observational evidence within scientific categories in iteration 4 to iteration 5 (iteration 5 had an extra tool and intellectual role for the child not holding the iPad). There was a significant difference in the scores for iteration 4 (averaged a score of 9) and iteration 5 (averaged a score of 10). Within the sociomaterial configuration of iteration 5 with the additional tool and role, small groups successfully discussed one additional piece of evidence (on average) in the 1-h program than the groups that did not have a specific role for the child not holding the iPad. We take our findings as a preliminary indication that during tablet-supported sense-making in science, fuller engagement in the argumentation and explanatory practices can be supported via adding a sense-making tool with an associated intellectual role to the child not holding the iPad tablet.

We found that utilizing the trialogical approach for a small group analysis allowed our team to take into account various sociomaterial resources and configurations for out-of-school time learning. We were able to determine how one sociomaterial configuration where each child who did not hold an iPad was given a small card with additional information and the intellectual role of "fact checker" and "evidence confirmer," led to teams discussing the tree life cycles with further detail and depth. We also found that learners coordinated their actions with the technology in order to accomplish the goals of the photo-task activity. For example, when one learner had the tablet and read the criteria aloud, the other partner made observations of the trees by identifying the evidence that matched to the tree onsite. In other cases, one partner would give confirmation to the partner to apply criteria to the tree. Most often, learners engaged in the activity as accountability partners to check and countercheck each other's observations and conclusions. In some episodes, when there were disagreements between the learners, one partner used the checklist as evidence to persuade the other partner why a certain specimen is not the specific tree type their team was looking for.

Analyzing Science Learning Within Each Group

To understand how these patterns the group analysis found manifest across the full dataset, we conducted a qualitative analysis of groups' meaning-making talk with a trialogical framework. The following episode with Richard and Ben exemplifies how the technology supported looking for evidence and fact-checking to develop a understanding of the observable traits of a tree's life cycle. The youths are trying to decide if the tree is a sapling combining observation of the setting and resources in the tool while engaging in a sense-making conversation:

Richard: Well, let's check. *[fact checker request]*
Ben: ((shakes tree's trunk)) Yeah, bendable. *[evidence confirmer]*
Ben: Yeah. ((reads from app's annotation tool)) Has a thin trunk that you cannot put your hands-
Richard: No, that you can.
Ben: But you can –
Richard: Yeah, it does, Trust me. *[evidence confirmer]*
Ben: Around chest height …
Richard: ((reads from app's annotation tool)) Does not have seeds or flowers.
Ben: ((looks at tree)) Does not have seeds or flowers on it. *[evidence confirmer]*
Richard: It doesn't. So, let me take it (photo).

At the start of this episode, Richard suggested that they check whether the tree is bendable (and therefore a sapling). Ben shook a tree to test to provide confirmation. Next, they had to come to a shared understanding of what a sapling was—whether you could or could not put your hands around the trunk at chest height. The two worked through this and realized that Ben misspoke "cannot" when he should have said "can." As this excerpt continues, the two learners exhibit similar patterns of behavior as before: checking the criteria and giving confirmation. In sum, the T.I. technology supported both Ben and Richard to engage in joint sense making. Ben who was holding the iPad became the content provider of the checklist, and Richard acted to test and confirm the criteria on the actual tree specimens. Ben and Richard are one example of how youths engaged with the sociomaterial resources to make sense of the life cycle of trees.

Implications

Given that we designed *Tree Investigators* to support families and children to engage in science practices related to trees, our work speaks to designing with sociomateriality perspectives in order to support science learning with mobile computers. Science education lends itself well to sociomateriality perspectives, given the conceptual, instrumental, and social nature of science teaching and learning (Duschl, 2008). We found that the blend of AR and mobile technologies, the trails and outdoor spaces, and natural and designed objects present in the nature centers could support learners sensemaking within and across various science practices (such as observation, explanation). Initially, we found (Zimmerman, Land, McClain, et al., 2015; Zimmerman, Land, Mohney, et al., 2015) that families engaged in high levels of describing and naming talk (Allen, 2002) around scientific observations; however, learners' conceptual (interpretive and explanatory) talk was less prevalent. In our later design iterations, we utilized the literature on scaffolding (Quintana et al., 2004; Xun & Land, 2004) to add more conceptual and participatory learning activities to our mobile AR experience. Learners increased their scientific vocabulary, noticed relevant features, increased conceptual talk, and accurately identified life cycle stages (Land & Zimmerman, 2015). In these later iterations, the use of a created digital artifact (a conceptual organizer made from pictures taken on-site at the nature center) was added as another sense-making tool—putting the youths in conversation with each other and the digital artifact as the youths made sense of important biological cycles present in their community, but previously unnoticed. Specifically, our work supports the inclusion of two digitals tools, digital photography and annotations, as scaffolds to support observations in the outdoors. In out-of-school time, video annotations shared between learners have shown to support learners (Stevens & Martell, 2003); our work adds the utility of annotations to photographs to support shared meaning-making in biology.

Conclusion: Theoretical Framework and Material Conditions

This chapter advances technologically enhanced outdoor science learning for out-of-school time with an empirical account of how the Tree Investigator app and its related pedagogy evolved over various research iterations within a design based research study. As our design approach evolved from a focus on placed-based education (with an original focus on learning in community spaces) to sociomaterial perspectives with a focus on place plus people's bodies, tools, material resources, and people, we were able to better support learning of biological concepts and sense-making, connecting talk. As our theoretical framework shifted from a dialogical (Allen, 2002; Leinhardt et al., 2002) to trialogical (Hakkarainen & Paavola, 2009) view to elucidate the sociomateriality of technologically enhanced learning, we were better able to focus on the scientific practice coordination of evidence with explanations.

Our work illustrates how theoretical frameworks and approaches to design, which operate at intersection of people, tools, and context, can evolve over time in design-based research projects.

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Part IV
Moving Forward

Chapter 15
Implications for Deep Learning: Unpacking the Practice of Teaching and Learning *with* Technologies

Isa Jahnke

Abstract This chapter adds the view on the implications for deep learning that I see when taking a practice lens on the material conditions of learning and teaching with technologies. Grounded in Jonassen's work on computers in the classroom, I develop the central place for *unpacking* the daily practice of learning *with* technology that spans the Learning Sciences and Educational Technology arenas. Learning with technology differs from learning about and from technologies. The term of teaching and learning *with* technologies has been shaped by David Jonassen many years ago. However, it is still relevant today, as it is shown in this chapter through the implications that it brings for the work of teachers, practitioners, schools, and researchers. Moreover, by using the approach of crossactionspaces, I provide an alternative view to the concept of teachers as workplace learners—the Teacher's Zone of Proximal Development (T-ZPD).

Keywords Didaktik design · Digital didactical designs · Instructional design · Mobile learning · Teacher's zone of proximal development · User experience · User research

Introduction

One of the goals of my work is to contribute to a deeper understanding of everyday practices by unpacking "what is really happening" and not what is expected to happen; read for example our work on how early-adopters and innovative teachers use tablets in their classrooms (Jahnke, Bergström, Marell-Olsson, Hall, & Kumar, 2017). In this chapter, the reader will be exposed to the idea of unpacking teaching and learning *with* technologies. This phrase has been shaped by Jonassen (1996),

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Table 15.1 Learning from, about, and with computers (Jonassen, 1996)

Learning *from* technologies	Learning *about* technologies	Learning *with* technologies
Drill and practice, tutorials, memorizing (surface learning)	Computer literacy	Deep learning
Learner has no input into the process; students are controlled by the technology	Learning about how to use the technology, and to understand how the computer works	Intellectual partnership, computer enhances learner thinking and learning
Computer program is programmed to teach the student, to direct activities toward the acquisition of prespecified knowledge or skills	Memorizing parts of facts about technologies is relatively meaningless; better would be to understand results from using not memorizing	Technology use to extend cognitive functioning during learning and engage learners in cognitive operations while constructing knowledge that they would not otherwise be capable of

published in his book "Computers in Classrooms." To understand his term, he differentiated the term from learning *about* or *from* technologies, read Table 15.1.

Jonassen conceptualized that a design for learning with technologies supports deep learning when students can make cognitive connections, expressed in "a-ha-moments," for example.

Deep and meaningful learning is a wishful strategy in education that tries to enhance learner deep learning outcomes (Howland, Jonassen, & Marra, 2012). However, the majority of studies in 1:1 classrooms, one device per student, focuses mainly on effects on learner motivation, student achievement, student engagement, collaboration, or measurements for deep learning (Fullan, Quinn, & McEachen, 2018; Harper & Milman, 2016; Smith & Santori, 2015; Tay, 2016)—but studies rarely describe the ways teachers and learners really make use of technologies and how material conditions play a role in this. While there is a demand from research for promoting deep learning with technologies (Fullan & Langworthy, 2014; Laird, Shoup, & Kuh, 2006), it is not clear whether or how this is really happening in educational settings. In the following section, I offer a view of how to study the practice of deep learning with technologies. In particular, I point to the challenges of what prevents or hinders deep learning with technology and its transformation by unpacking the everyday practice of the happening.

Unpacking the Use of Technologies and Material Conditions from the Teacher Perspective

By unpacking the practice, I try to describe how the users actually use the technology. This view is related to usability studies and user research that investigates the user's experience (UX) with a digital system for example. To improve the practice, the user's lens will help to reveal problems and critical situations when using digital tools. The use of technologies or systems cannot be studied without the understanding of the material conditions of such tools or systems. Technical systems have been engineered with a special purpose, and they are created by a designer or software developer who is not the actual user (not the teacher or student). The social practice of the users with the technologies evolves and may differ from the purpose of the material conditions that the software development team have had in mind.

In this volume, many authors contribute to the perspective on unpacking the practice. For instance, Cerratto Pargman contributes from a perspective of sociomateriality to unpack emergent teaching practices with digital technology. In her analysis of the teaching practices observed, she clearly points at what changes when digital technology is used in the classroom, and at how researchers and teachers can identify these changes. Håkansson's work explored how teachers in schools made use of technologies. Her results show that teachers supported students to "see" the laptop as a *school tool* not as a tool to play with. Teachers noted the importance of pedagogical reflection, but they also faced technical challenges that created a hurdle for what they actually wanted to do. The impact of the technical-material condition is underestimated. The work presented by Mårell-Olsson, Bergström, and Jahnke demonstrated that principals' visions impact teachers' everyday practice. Teachers struggled to provide a student-customized education, and for some teachers the tablet is rather a *teacher tool* (e.g., distribution of information and assignments), while for other teachers it became a *student tool* that enhanced student activities *with* tablets *not from* the technologies. Also, Adams presented findings from a science teacher. She showed that a teacher is a "critical agentic bricoleur," a person who creates something depending on whatever materials and resources are available. The teacher made use of a text message tool to enhance collaborative learning for science education, and this led to a positive learning culture of mutual trust, collaboration, and academic success. A study by Kopciewicz and Bougsiaa reveals conflicts and tensions of the teacher experience in tablet classrooms. Teachers were first excited when they heard their schools got tablets, and with that they developed a "hope" and expectation that the tablets will work "wonders" to cause radical changes in the classrooms (read also Jahnke, Svendsen, Johansen, & Zander, 2014, "the magic silver bullet"). "However, nothing like that happened," wrote the authors. The teachers began to wonder "and then what?" as they tried to find new ways to integrate the tablet in the classroom. Mørch, Murad, Herstad, Seibt, and Kjelling described the application of Monoplant, a prototype to provide teachers and high school students with hands-on experience on plant biology. Students had difficulty connecting their textbook knowledge with the Monoplant experience, and the teacher became central by enabling the students to "connect" concrete experiences to a more abstract language as used in the textbook (e.g., scientific concepts and terminology). Jaldemark, Bergström, and Mozelius adopted a location-based game for mobile devices built on the idea of Pokémon GO. Their results demonstrate how teachers orchestrated new forms of learning processes by linking them to students' resources that were entwined in the everyday lives of students. This new emergent practice of teaching and learning may benefit from building links to students' everyday phenomena.

Unpacking the Use of Technologies and Material Conditions in Informal Learning

While the previous section shows how the studies contribute to unpacking the use of technologies in schools and formal learning, this section here adds that researchers also can unpack the use of technologies for deep learning in informal settings. It means that deep learning can happen at many places, in schools, outdoors, and in informal or nonformal learning.

Various contributions in this edited book have been engaged with unpacking the use of technologies while taking account of the specific conditions of informal learning. For instance, Kyza and Georgiou showed the development of an augmented reality (AR) technology called TraceReaders for students mainly in 11th grade in a summer club. Their findings reveal the challenges of instructional design that neglects but should consider aspects of materiality during learning with AR technologies in outdoors settings. Savva, this volume, analyzed museum–school partnerships to expand digital literacy practices. Students generated a virtual museum to support STEM curriculum for primary schools. Her work reveals how students engage in a multiliteracy practice as active designers and multimodal learners. It is also the case with Waldmann and Sullivan's work in this volume which uncovers language learning practices of two bilingual children living in Sweden, a 3-year-old and a 6-year-old. They demonstrate how children learning a language at home by using mobile video chats, and how the tool engaged them in language participation practice. Finally, Toomey Zimmerman and Land studied the interdependencies of a mobile app and pedagogy in outdoor learning using the developed app of Tree Investigators. The app combines augmented reality and digital photography app, to support families and children to engage in science practices related to trees. They demonstrated how socio-materiality affects deep learning with technologies.

Implications of Unpacking the Practice of Teaching and Learning with Technologies Toward Deep Learning: Looking Forward

If deep learning is an increasingly important objective, there is a need to unpack the practice, and then, with this new knowledge, research may help educational practitioners, decision-makers, and teachers to understand how to make the most of the resources available to support deep learning. Recent work emphasizes the need of studying the connection of teaching and deep learning. Bogard, Consalvo, and Worthy (2018) point out that it is vital for teachers to provide students with an environment that promotes deep learning. Borgen and Hjardemaal (2017) make the point that there is not much research about how educational objectives, content, teaching methods, assessment forms, learning processes, and deep learning outcomes are linked together. Fullan and Langworthy (2014) describe new pedagogies for deep learning. Also, Naylor and Gibbs (2018) and Lim, Ong, Soh, and Sufi (2016) demonstrate the need for teacher training for deep learning. Studies show that deep learning is important; however, it is not always clear how teachers can prepare their teaching so that students get access to a learning process that promotes deep learning. In this book, we shed light on the practice and challenges and hurdles of teachers and learners when putting deep learning with technologies into practice. Based on the ideas and concepts presented in this volume, I can derive several implications for research and practitioners.

Implications for Schools and Other Practitioners in Education

For schools and other forms of educational practice, the studies in this book make the point that teachers need technical support, which is quite obvious—but even more important teachers need professional development programs that help them to co-design learning with technologies. Such programs should empower teachers to be learners at the school workplace by utilizing the approach of a "Teacher Zone of Proximal Development" (T-ZPD) (Vygotsky), and this means to identify what teachers can do without help versus what they cannot do. For many years, teachers' work has been seen as *teaching*, and teaching only. This neglects that teachers are designer of learning and also workplace learners. The primary work is still teaching, but in order to do it in the digital age, teachers have become "designers for deep learning," and with it, teachers' teaching cannot be reduced to teaching anymore but encompasses many other work tasks such as management of technologies, classroom management, teaching, learning and assessment design updates, as well as content updates.

Besides the obvious things, that we already know, the most important element is that teachers get access and join *reflective conversations and coaching* as part of their working hours in schools.

Here are two examples. The first example is from the P. K. Yonge Developmental Research School at the University of Florida in Gainesville, Florida. The school decided to drop the traditional model of "one teacher per class," but many teachers share responsibility for one class. The school created a space in the center of the main building where teachers were allocated space and time for peer collaboration and peer coaching. Each week, for example each Friday, they got 2–3 h to prepare, discuss, and reflect on deep learning with technologies. The school not only created a new mindset for teachers as workplace learners and designers but also built spaces and assigned time for reflection about everyday practices in classrooms. The school assigned a materialized space for the activity of teachers' collaborative reflections.

The second example shares the approach of eMints at the University of Missouri-Columbia. eMints is a center for supporting teacher professional development in Missouri. One of their approaches is online video coaching for teachers. This is how it works: A teacher works with an eMints coach to discuss what the teacher wants to change in her or his classroom practice. Then the teacher implements the changes and video-records parts of the classroom in action. After the classroom, the teacher watches the recorded video and annotates the video (e.g., what was good), indicating hurdles and suggesting improvement. Also, the coach watches the video and annotates. After that, the teacher and the coach meet online and go through the annotated video to create an action item plan, especially, what to improve. Then the cycle starts again.

This external coach approach might be also adopted for teacher peer coaching but only if teachers would get training in becoming a coach—a specific method of active listening, asking questions and proposing action items. Both the external and the peer coaching approach means to have broader organizational changes; coaching needs to be embedded into the school practice, that is, 1–2 h per week (e.g., 8–10 each Friday), would be allocated to teacher coaching.

Providing reflective coaching elements is one possible implication. Another one is to share resources for teachers and educators that they are able to educate themselves. The reflection piece itself may not be sufficient, rather it may be embedded into a broader set of constructively aligned activities (Biggs & Tang, 2007). Figure 15.1 shows such a framework for deep learning with technologies (Jahnke, 2015; Jahnke et al., 2017).

The framework includes five elements and their constructive alignment with each other: (a) teaching and learning goals, (b) learning activities, the teachers *plan how to* achieve the goals in such a way that the learners are able to develop deep learning outcomes, and (c) iterative process-based assessment to support student growth. Process-based assessment is the most effective method but summative assessment is still the common routine (Bergström, 2012). The framework also includes (d) the design of social relations among learners and learners to others (e.g., teachers) and pays attention to the group dynamics that may foster or hinder students to become co-designers of deep learning, and (e) adopts mobile technologies.

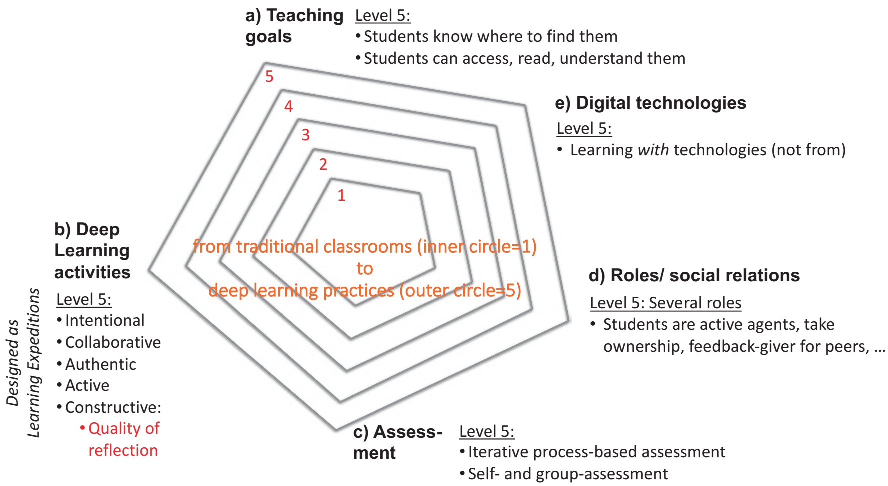

Fig. 15.1 Framework for a deep learning design (pentagon model). Teachers learn how to conduct deep learning represented as level 5. The model focuses on classroom practices. Each of the main elements (a–e) has five levels

Implications for Research

With this chapter, I want to contribute to a short summary of the importance to unpack the everyday practices and the material conditions that characterize learning and teaching today in different contexts, milieux, and geographical contexts. The perspective of unpacking the use of technologies in teaching and learning may challenge current understandings and entice us to redefine everyday practices, and in certain cases, to envision and imagine them in new forms.

In the digital age, we are probably the last generation that made a clear distinction between off-line and online worlds (Floridi, 2014). The world is changing toward a sociotechnical society (Jahnke, 2009) that is a network of social and technical systems. More specifically, it consists of mutually dependent interwoven networks and processes of human communication and controlling human–computer interactions that can be distinguished from the environment of other systems (Fischer & Herrmann, 2011). In this sense, there are many different *sociotechnical systems* in a sociotechnical society, not just one. While this lens is still useful for *designing* human-centered technology in organizations, it does not sufficiently describe the social and technical *dynamics* of our everyday practices in a sociotechnical society today. In these new circumstances, teaching and learning practices are challenged yet again.

With Web 2.0, started around 2005, the sociotechnical society was characterized as a living lab of free participation. Online communities were mainly built on trust: first phase, read Table 15.2. Over the years the online communities evolved clear rules of how to participate. For example, roles and policies were created; however, these rules have been made accessible for users to understand (second phase). In the third phase, corporate groups (e.g., Internet providers, banks, and stock exchange) developed technical mechanisms to manage and enforce social behavior; however, this time, the "rules" are manifested in algorithms and not available for the public and for most people obscure. Hidden structures have been developed.

Table 15.2 Sociotechnical society interfused with crossactionspaces (Jahnke, 2015)

First phase	Second phase	Third phase	Fourth phase
(a) Mainly trust-based virtual communities, very informal rules (architecture of free participation)—living lab of freedom	(b) Clear rules (conventions, boundaries, etc.) that are mainly socially enforced—network of policies	(c) Additional rules/mechanism that are technically determined but for most people obscure	(d) Society is *interfused* with crossactionspaces (Jahnke, 2015): sociotechnical communicative actions by humans and bots (most people cannot tell the difference)
For example, Wikipedia's stage in 2005	For example, Wikipedia in 2010	For example, Google page ranking, loan algorithms	For example, spreading misinformation and false information by bots
→ Evolving toward a *sociotechnical* society: Society is interfused with dynamics of crossactionspaces →			

We are currently living in the fourth phase (Table 15.2), in which the sociotechnical society is interfused with highly dynamic spaces of communication and information sharing that I call "crossactionspaces" (Jahnke, 2015). Such dynamic spaces emerge and disappear through crossing actions of humans and bots, news and fake news. Most people cannot tell the difference whether they receive the information from a bot or a person, and most people have difficulties to evaluate the quality and truthfulness of the content (Stanford History Education Group, 2016). Crossactionspaces (e.g., Twitter, Facebook, mobile microlearning and augmented reality (AR) and virtual reality (VR) platforms, show high tensions between openness and constraints; they are volatile, uncertain, complex, and ambiguous. Participants of these spaces perceive the communication and the information as a duality of controversial structures and as given objective facticity (inspired by Berger & Luckmann, 1969). It means, on the one hand, people build crossactionspaces, just when they share posts or reply, but, on the other hand, they also perceive such existing spaces as a *fact* in front of them that threaten them and limit their possible actions.

The dynamics are intense, for example, when a person receives the same message hundreds of times. The danger lies in the repetition, as researchers have shown that repeated false information makes people to believe that it is true, and even if a person knows the truth, this knowledge does not protect against (Fazio, Brashier, Payne, & Marsh, 2015) the so-called illusory truth effect. In addition, the social group does not protect either and can hinder the authentication of false or correct information (Jahnke & Kroll, 2018). The belief of a person triggers her/his search terms, and so instead of asking "what shape is earth," they choose to use "earth is flat" into the Internet search engine—and the Internet has all kinds of "truths," but not all are correct or right. Awareness about the dynamics of crossactionspaces, how and what information gets distributed, and the usage of search terms is relevant to evaluate false from correct information. There is much more research required to understand these everyday practices, and we plead to intensify research of these everyday practices, especially when they enter teaching and learning situations.

Soon schools and other educational practives will have augmented and social virtual realities platforms in their own environments of higher education, nonformal learning (e.g., museums) or workplace learning (Goggins, Jahnke, & Wulf, 2014). The study of unpacking the actual practice and, thus, to contribute to a deeper understanding how participants take agency in such new emerging crossactionspaces is more important than ever. Such mixed spaces can be built according to "reality" but also can support fake realities (Erdelez & Jahnke, 2018).

As I propose to expand the research of unpacking the use of technologies with UX, user research, and usability studies, I hope it will contribute to a new knowledge foundation that may help researchers, designers, and practitioners to support and empower the learners and the teachers to actually then become *co-designers* of their learning—to break out of the receptive habitus and start actively shaping learning and teaching. To accomplish this goal even further, beyond this chapter, I encourage the reader to look at *pedagogical usability* of sociomateriality as a useful tool on the way to implement meaningful learning *with* technologies instead of only learning *from or about* technologies (Jonassen, 1996).

Outlook

With this chapter, one of several goals is to shed light onto the importance of studying everyday practices and their material conditions. In particular,

Putting a focus on unpacking the practice: Studies are needed to analyze how teachers make sense of material conitions such as tablets or resources, and how students and teachers shape their own agency.

Looking beyond teaching goals, learning activities, and assessment: Research of learning and teaching needs the additional look of sociomateriality and social relationships, and thus is more than just looking at the constructive alignment of teaching goals and leanring and assessment (Biggs & Tang, 2007); material conditions shape the space *for* teaching and learning and therefore shape the action of doing "teaching" and "learning."

Situating the relevance of material conditions into spatial situational awareness: With mixed reality platforms of AR and VR in educational pratices, it becomes important to unpack the practice of what is really going on versus what schools or researchers expect to be happening. Using such technology shapes learning into a crossactionspace (Jahnke, 2015) in which this space itself shapes teacher and student actions. The spatial explorations of users in augmented or social virtual reality will become the "message" for the learners (McLuhan, 1967)—how will instructors and learners make sense of the new crossactionspaces for their learning, training, and teaching? How will it shape the participants and how will participants shape their learning? These are research questions that should be answered.

The studies and examples presented in this chapter give us only a glimpse of the actual practice and there is much more out there to explore, to make it visible, and, thus, to give it access to a critical view, to discuss, and to detect problems, challenges, and hurdles. From this perspective, I want to encourage the reader to be part of "unpacking the practice" and contribute to implications toward improving the practice.

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Chapter 16
Next Steps: Toward a Relational Mode of Thinking for Educational Technology

Teresa Cerratto Pargman and Isa Jahnke

Abstract The work presented in this edited volume brings together inspirational and high-quality chapters that call for more conversations in our field. Together with critique and care, we hope the work initiated here will continue disentangling, assembling, and giving form to new arguments able to structure a more nuanced and deeper dialogue on teaching and learning with digital technology.

Toward a Relational Mode of Thinking for Educational Technology

The studies and examples presented in this volume contribute to exploring emergent practices and material conditions in teaching and learning with technologies. They provide us with a myriad of questions, constructs, methods and perspectives of contemporary forms of learning and teaching, as well as on design of technologies in education. In particular, through their findings and insights, these chapters raise an important set of issues. For instance: What does it mean for designers of educational technologies to support sociomaterial practices? What new opportunities for digital technologies are yet to be envisioned? How do researchers and designers think about innovation in education when taking a lens focused on practices? What are the relevant analytical constructs for scrutinizing learning and teaching with technologies when we approach them as sociomaterial assemblages? How does a lens focusing on practices and material conditions inform the design of technologies for education? How do sociomaterial approaches redefine established understandings of learning and human cognition? How do we evaluate design interventions crafted

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from sociomaterial views on learning and teaching? How do we appraise "what is being valued" in educational technologies?

Further along the road, these questions entice us to continue the journey started here, and by doing so to come closer to innovative, alternative, complementary ways of thinking about teaching and learning with technologies. As editors we know that such a journey is far from being a linear process. It takes time and many conversations to treat educational practices as relational, composed, and emergent, as well as to engage with issues that question mainstream modes of thinking in our field. In a sense, this volume is also illustrative of this effort and of the developmental work that characterizes an ongoing process where two distinctive modes of thinking meet and come together. These distinctive modes of thinking we refer to here are what Decuypere and Simons (2016) call the *representational* and the *relational way of thinking*.

More precisely, the representational way of thinking differentiates between humans, human knowledge and the natural world as it is, while the relational way of thinking considers these entities or actors simultaneously; "… that is to say, in relational thinking, anything might potentially relate with anything else, and this without assuming a priori differences between different actors" (Decuypere & Simons, 2016, p. 30). These two modes of thinking become inevitably entangled when attempting to explore emergent practices and material conditions in teaching and learning with technology. However, from such an entanglement we learnt about the weight of scrutinizing the relations between actors and the relative position that each actor has in a web of relations at a specific time in a specific context. Engaging with a relational mode of thinking thus presents implications for how we can consider learning, teaching and agency.

Following Säljö (2019), in this volume, learning is about presenting how cultural tools, symbolic technologies and our thinking and communication come into being and how together they become reflected in intellectual practices and instrumental acts of thinking and arguing. Viewing learning in this way helps us understand teaching as an act of gathering and assembling a variety of actors that are present for someone in a particular situation, and composing, from these relations, a meaningful account for others and for oneself. In these accounts of learning and teaching, the term "agency" also gains attention, as it is not here seen as "a property of an actor but rather a distributed effect of different actors" (Decuypere & Simons, 2016, p. 31). This understanding of agency becomes clear when reasoning about the role of educational technologies in learning and teaching; digital technologies do not present a value per se, but rather become valued only insofar as other actors value them.

In summary, the work presented in this volume is instrumental in how representational and relational modes of thinking meet, and how such an encounter can be generative of intellectual challenges but also of resources supporting researchers, practitioners, and designers who aim to contribute to schools and education from a creative and critical stance. Moving forward, we are confident that the work presented in this volume contributes to creating new links within the current narrative about human practices and digital technologies in education, and it also raises awareness of our position as researchers and designers in the web of the relations that make up the educational practices and settings with which we engage.

Finally, we walk away from this volume with happiness and satisfaction. We believe we have shared new questions that we hope will intellectually stimulate colleagues in our field to pursue the task started here. The work presented here is thus a call for more conversations in which, together with critique and care, will continue the work of disentangling, assembling, and giving form to new arguments able to structure a more nuanced and deeper dialogue on teaching and learning with digital technology.

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Correction to: Emergent Practices and Material Conditions in Learning and Teaching with Technologies

Teresa Cerratto Pargman and Isa Jahnke

Correction to:
T. Cerratto Pargman, I. Jahnke (eds.), *Emergent Practices and Material Conditions in Learning and Teaching with Technologies*, https://doi.org/10.1007/978-3-030-10764-2

This book was inadvertently published with missing citations. This information has been introduced into the updated book.

Page 18, 1st paragraph

Yet, both approaches are concerned with provoking creative critique. Creative critique is here understood as the ability to intervene in discourses and realities so new insights about how we relate to technologies for learning and teaching are generated **(cf. Decuypere & Simons, 2016**).

Page 35, 2nd paragraph

By reading Schatzki **(2001 p.7),** we **learn** that most of the theorizations on practices conceive practices as arrays of human activity that are underpinned by **"capacities such as know-how, skills, tacit understandings, and dispositions,"** and a minority of them underscore that the activities bound into these practices also include those of nonhumans such as machines. (…)

The updated online versions of these chapters can be found at
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T. Cerratto Pargman, I. Jahnke (eds.), *Emergent Practices and Material Conditions in Learning and Teaching with Technologies*,
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Page 35, 3rd paragraph

Following Schatzki (2001) we understand that current practice **approaches** can be characterized by two central traits. One of these traits is the idea that practice is embodied, (…)

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Jo Herstad is an Associate Professor in the Department of Informatics, University of Oslo. He received his PhD in Informatics from the University of Oslo (2007) and an MS in Computer Science (1988) from the Norwegian University of Science and Technology. Between 1988 and 2003, he worked with telecommunications technologies for Ericsson in Norway, Singapore, and the USA. His research area is human-computer interaction, with a special interest in universal design and the design of mobile technologies. Currently, he is studying the use of robots for stay-at-home elderly, with a specific focus on robot movement and interaction with robots. His long-term efforts include understanding and describing the human-computer relationship. This is pursued through empirical investigations of computer use in various settings, such as homes, universities, and public places. Herstad participates in the following research communities: human-computer interaction (HCI), universal design (UD), and computer-supported cooperative work (CSCW). He is involved in teaching user-centered design for bachelor students and interaction with AI for master's students.

Jimmy Jaldemark is an Associate Professor in the Department of Education, Mid Sweden University, Sundsvall, Sweden. He has worked within the field of technology-enhanced learning (TEL) for more than 20 years. He is the leader of a research group called Higher Education and E-Learning (HEEL). In addition to researchers from Mid Sweden University, HEEL also involves scholars from Umeå University and the Royal Institute of Technology, Stockholm. The research within this group focuses on networked, mobile, and collaborative aspects of learning in higher education. Since 2013, Jaldemark has led an international virtual research seminar that he founded.

This seminar embraces issues within the field of TEL in higher education. Within the field of TEL, he is also engaged in writing, editing, and reviewing papers for 14 scientific journals. He recently published a special issue in the *British Journal of Educational Technology* with the theme "Collaborative learning enhanced by mobile technologies." He is currently editing a Springer book project with the theme "Networked learning and professional development" to be published in 2019. He also is a co-founder of a national research school called GRADE (Graduate School for Digital Technologies in Education). The project is funded by the Swedish Research Council and affiliated the first doctoral students in 2018. In earlier work, he focused on various issues, such as participation in computer-mediated communication, designing for learning, educational technology, online supervision of student dissertations, social media as a tool for learning, and mobile learning.

Morten Kjelling is a Web Developer and Interaction Designer working as a consultant in Clave Consulting. Morten received his master's degree in Informatics, Design, Use, and Interaction from the University of Oslo in 2014. Together with Sjur Seibt, he developed and designed Monoplant, which later was used in conducting the research for the master's thesis they wrote together. He has a combined interest in interaction design and development and the continuing iterations and interactions between the two fields in design processes. Kjelling has been involved in multiple learning applications in the field of popular science (Tall forteller, Tricks of science). https://leonov.bandcamp.com

Lucyna Kopciewicz is a Professor of Education at the University of Gdańsk, Poland. Her main research interests lie within the areas of cultural studies, media studies, sociology of education, and gender studies, with a special focus on socialization and the materiality of learning in family and school cultures. Her work is rooted in theories on educational inequalities and sociocultural and critical theory. She leads and participates in several national and international research projects. In her research, she focuses on processes of social transition, learning, social justice, and educational culture and its democratization in Poland. She has authored and coauthored 80 scholarly books and articles. Her current research project deals with mobile technologies, new generation, and changing patterns of socialization and learning. It seeks to contribute to the study of how mobile technologies reflect and transform established learning practices in home and school settings.

Eleni A. Kyza is an Associate Professor in Information Society with the Department of Communication and Internet Studies at the Cyprus University of Technology. Her research interests focus on the investigation of computer-supported collaborative inquiry learning and the design of technology-enhanced learning environments at different levels of education to support motivated, meaningful, and reflective practices. Her current research areas include scaffolding inquiry learning in nonformal and informal spaces using augmented reality technologies, collaborative learning, participatory design with teachers and students, and promoting media literacy, scientific reasoning, and active and responsible citizenship in young people. She is the Program Director of the master's program "New Technologies for Communication and Learning," and she leads the Media, Cognition, and Learning Research Group (http://mcl.cut.ac.cy). With her collaborators, she has developed learning technologies based on learning sciences theories, such as the web-based reflective inquiry, learning and teaching platform, *STOCHASMOS*, which has enabled the investigation of scaffolding to support middle school students' scientific literacy practices and inquiry-based learning, and *TraceReaders*, an augmented reality platform for scaffolding students' inquiry learning in informal contexts. She is an associate editor for the *Instructional Science* journal and a member of the editorial board of the *Journal of the Learning Sciences*. Since 2015, she has served as Secretary/Treasurer of the European Association for Research on Learning and Instruction (EARLI). She is the Past-President of the International Society of the Learning Sciences (ISLS) and an Inaugural Fellow of the ISLS.

Susan M. Land is an Associate Professor in the Learning, Design, and Technology Program at Penn State University, University Park, Pennsylvania. She earned a doctorate in Instructional Systems from Florida State University. Previously, she worked as a postdoctoral fellow at the University of Georgia's Learning and Performance Support Laboratory and held a faculty position at the University of Oklahoma in the Instructional Psychology and Technology Program. Before that time, she consulted on instructional design projects with organizations such as the US Air Force Academy, Citibank, and Hewlett-Packard. Land's research emphasizes frameworks for the design of open-ended, technology-rich learning environments. A common thread of her research involves how to better understand and support the processes whereby learners more deeply and meaningfully engage in learning with technology in student-centered learning contexts. Land's research group is investigating the design of learning environments afforded by new media in everyday, informal, or classroom contexts that utilize technologies such as social media and mobile devices. Recent research projects have studied the use of digital photography and mobile devices to capture everyday experiences that connect home-school learning; context-sensitive, place-based mobile learning in outdoor informal environments; and frameworks for the design of mobile, augmented reality learning.

Mariana Landau is an Associate Professor at the Social Science Faculty at the University of Buenos Aires, Argentina. Since 2016, she has led research regarding the integration of technologies in the educational system. In their first steps, these studies were related to the way in which social media mediates the educational discourse. Now, the work is oriented toward analyzing the interactions in different educational environments mediated by Information Communication Technologies (ICTs).

In addition, she leads a project about museums and schools whose objective is to design digital content for K-12 students. This project is financed by the Ministry of Education of Argentina.

Since 2006, Landau has also taught for the Education, Language and Media master's program at the National University of General San Martín, Buenos Aires, Argentina.

She has several scholarly publications: 2 books as author and editor (in collaboration), 13 book chapters, and 5 articles in specialized reviews. Between 1998 and

2006, she participated in several research groups at the University of Buenos Aires, in which she dictated several training courses for teachers and participated in various academic events.

Eva Mårell-Olsson is an Assistant Professor in the Department of Applied Educational Sciences at Umeå University. She has many years of experience in process development supported by technology in the education sector. Her research interest is the innovative use of mobile and emergent technologies such as wearable technology and how these technologies can enhance teaching and learning in different ways. One study funded by the Swedish Research Council (2014–2016) examined how teachers design their teaching with the use of tablets in one-to-one (1:1) classrooms in Sweden. Another part of her research concerns wearable technology and, more specifically, how smart glasses can be used in various fields and disciplines. Recent studies within this area (2013–2018) concern the possibilities and challenges in the use of wearable technologies in higher education, schools, dentistry, emergency care, and industrial area. Currently, she is leading two projects focusing on how gamification as an emergent teaching practice, together with the use of emergent technologies such as augmented reality (AR) and virtual reality (VR), can enhance teaching and learning in higher education and schools.

Anders I. Mørch is a Professor of Technology and Learning in the Department of Education of the University of Oslo. He received his PhD in Informatics from the University of Oslo (UiO) and an MS in Computer Science from the University of Colorado, Boulder. He developed educational software at NYNEX Science and Technology Center, New York. Mørch has been employed at the Faculty of Educational Sciences, UiO, since 2001 and, previously, in the Department of Information Science, University of Bergen, and the School of Engineering, Oslo University College. His general research interest is understanding the role of tools and artifacts in how people develop and learn (distance learning, computer-based scaffolding, end-user tailoring, makerspaces) using collaboration, design, and modification as underlying perspectives. Over the past 7 years, Mørch has studied collaborative learning and end-user development in virtual worlds (Second Life, Minecraft). Previously, he designed, built, and studied critiquing systems and pedagogical agents (precursor to learning analytics). Currently, he is involved in a project to study the influence of a makerspace on motivation and achievement for gifted and talented children (GT-make). His long-term efforts include developing a design-based model of human learning and development (Evolving Artifacts Framework). Mørch participates in the following research communities: computer-supported collaborative learning (CSCL), human-computer interaction (HCI), end-user development (EUD), and computer-supported cooperative work (CSCW). His website is https://www.uv.uio.no/iped/english/people/aca/andersm/index.html.

Peter Mozelius is a postdoctoral researcher in the Department of Computer and System Science at Mid Sweden University, Östersund, Sweden. He has during the last two decades worked as a teacher in software engineering at various universities where he has developed about 20 courses. His research interests are in the areas of technology-enhanced learning (TEL), game-based learning (GBL), and information and communication technologies for development (ICT4D) with around 100 publications during the last decade. Apart from several international collaborations, he is also part of the research group called Higher Education and E-Learning (HEEL) at Mid Sweden University. Peter is currently involved in research projects regarding the evaluation of the active learning classrooms (ALCs) and the development of a testbed for distributed e-health. Peter is currently developing a course for professional development of primary and secondary school teachers aligned to the introduction of programming as a part of Mathematics and Technology in Swedish schools. A brief CV and a list of recent publications can be found on: https://www.miun.se/en/personnel/petermozelius/.

Hani Murad holds a MSc in Informatics (Technology, Organizations, and Learning program) and an MPhil in Health Economics, Policy, and Management from the University of Oslo (UiO). Currently, he is a tutor for both bachelor and master's informatics students at UiO and has a wide experience in teaching and supervising students' projects in interaction design, developing IT competence in organizations, and developing mobile information systems and services from the ideation to implementation phases. Students' projects are organized in collaboration with local high-tech industries, hospitals, and research centers. His research interests include scientific inquiry-based learning and the role of digital representations of complex scientific phenomena in expansive classroom learning. Furthermore, Murad is interested in developing user-friendly interfaces to support collaborative learning (CSCL) and cooperative work (CSCW) and in exploring how digital artifacts may be modeled and designed to mediate knowledge building and management in organizations.

Roger Säljö, PhD, Dr h.c.mult., and professor, works at the University of Gothenburg. His background is in educational psychology, and he specializes in research on learning, interaction, and development from a sociocultural perspective. Much of this work is related to how people learn to use symbolic technologies and how they acquire competences and skills that are foundational to learning in a socially and technologically complex society. In recent years, he has worked extensively on issues of how digital technologies transform learning practices inside and outside formal schooling. He is the Director of the Linnaeus Centre for Research on Learning, Interaction and Mediated Communication in Contemporary Society (LinCS), a national center of excellence (CoE) funded by the Swedish Research Council (2006–2018). He has been a Finland Distinguished Professor (FiDiPro) of the Academy of Finland at the Center for Learning Research at the University of Turku. He is an Honorary Doctor at the University of Turku and the University of Agder and an Honorary Professor at the University of Bath, UK. He has been a Visiting Professor at several universities, including the Universität Konstanz, the University of California San Diego, Rijksuniversiteit Utrecht, the University of Oslo, Georg-August-Universität Göttingen, the University of Agder, and the University of Stavanger. Säljö is a member of the editorial boards of several scientific journals and a founding co-editor of *Learning, Culture and Social Interaction*. He has supervised 50 students at 6 different faculties to their PhD degrees. He has published almost 500 articles, chapters, books, and other scholarly publications.

Stefania Savva is a Postdoctoral Research Fellow at the Cyprus University of Technology who secured €120,000 in funding for 2 years awarded by the Research Promotion Foundation under the RESTART Didaktor Program 2016–2020 (HORIZON 2020). Her postdoctoral research is entitled "Museum Affinity Spaces (MAS): Re-imagining Museum-School Partnerships for the 21st Century through a Multiliteracies Lens." Stefania completed a PhD in Museum Studies at the University of Leicester, UK, in 2016, with a focus on developing innovative museum-school partnerships to support diversity and multiliteracies-based pedagogy for the twenty-first century. Following her undergraduate studies in Primary Education in Greece, she completed an MA in Art, Craft, and Design Education in London in 2009, focusing on art education curriculum for social change and inclusion. Since 2012, Stefania has been working as a Research Associate of the Art and Design E-learning Lab at the Cyprus University of Technology, supervised by Dr. Nicos Souleles. In her work, she has focused on EU-funded projects on Design for Social Change, Innovation, and Entrepreneurship, and she has conducted research on the instructional use of iPads in Art & Design Education. Concurrently, she has been working with diverse children and adults since 2009 as part of her work as a primary teacher and museum educator. Stefania has made a number of presentations at international conferences following the receipt of Scholar Grants, and her work has been featured in academic peer-reviewed journals and edited volumes. She also has three chapter manuscript publications in progress and two papers accepted to be published in 2019. She is particularly fascinated by work in the field of inclusive museum learning, design thinking, technology-enhanced learning, and social change.

Sjur Seibt holds a master's degree in Informatics: Design, Use, and Interaction from the University of Oslo. Together with Morten Kjelling, he developed and designed Monoplant, which later was used in conducting the research for the master's thesis they wrote together in 2014. In recent years, Seibt has created web interfaces for health services at the Norwegian Directorate of eHealth. Currently, he does digital storytelling, combining journalism and technology at the Norwegian public broadcaster, NRK.

Kirk P.H. Sullivan is a Professor of Linguistics at Umeå University, Sweden. After having been awarded his PhD in 1992 and working in higher education in New Zealand and Sweden, he realized that he had a growing interest in education and enrolled in the University of Bristol's EdD program, obtaining his education doctorate in 2010. Today, Dr. Sullivan's research interests lie at the nexus of linguistics, education, cognition, and, frequently, technology. He has held a number of research grants; heads Umeå University's postgraduate school within the field of the educational sciences; publishes in journals such as the *British Journal of Educational Studies*, *Journal of Second Language Writing*, and the *International Journal of*

Multilingualism; and recently co-edited two anthologies, *Perspectives on Indigenous Writing and Literacies* and *Observing Writing: Insights from Keystroke Logging and Handwriting*, which will be published in 2019.

Christian Waldmann is an Associate Professor of Scandinavian Languages in the Department of Swedish, Linnaeus University in Sweden. Waldmann completed his PhD at Lund University, Sweden, in 2008, focusing on first language acquisition of grammar. With a background in linguistics and language acquisition theory, his current research interests include (technology-enhanced) language learning and support in formal and informal learning contexts and cognitive aspects of writing development in students with and without special needs. He is currently participating in a longitudinal project in which the team is studying the role of language and reading skills for writing development during compulsory schooling. In earlier work, he explored the potential of technology for supporting the revitalization and maintenance of indigenous languages. His research is presented at international conferences and published in academic peer-reviewed journals such as the *Nordic Journal of Linguistics* and *Language Acquisition*. Since 2017, Christian has been the Vice President of the Swedish Association for Applied Linguistics (Association suédoise de linguistique appliquée).

Heather Toomey Zimmerman, an Associate Professor of Education at Penn State University, is a Learning Scientist who studies how multiple learning experiences contribute to the development of knowledge, practices, and identity toward (or away) from science. Her research combines theories from informal learning, place-based learning, and learning on-the-move to create learner-centered environments deployed on mobile computers and in informal settings such as museums and libraries. Her current research topics include everyday science learning, parent-child interactions, designing for learning in informal institutions, and technology to support learning across settings. Her prior professional experience involved designing and implementing museum programs for families, youth, and community organizations—including the Storybook Science early childhood science/reading program and camp programs for rural and urban youth in their communities. She has published in the *Journal of Research in Science Teaching*, *Science Education*, *International Journal of Science Education*, *Research in Science Education*, *Journal of Museum Education*, *Environmental Education Research*, *Museums & Social Issues*, and the *Proceedings of the International Conference of the Learning Sciences*. She is active in the American Educational Research Association's Informal Learning Environments Research (ILER) special interest group and in the National Association for Research in Science Teaching (NARST) Science Learning in Informal Contexts Strand.

Index

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