

## CHAPTER 8

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# THE METHODOLOGICAL TORTOISE AND THE TECHNOLOGICAL HARE

## A Discussion of Methods for Conducting Research on New Technologies and Young Children<sup>1</sup>

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### INTRODUCTION

This is an interesting time to conduct research with educational technologies for young children. Technological advances are leading to an increasingly diverse and accessible set of available tools for this age group. Mobile devices, touchscreens, apps costing a fraction of computer software titles, and intuitive, user-friendly interfaces have allowed a quickly growing portion of the population—including young children—to become regular technology users.

While new technologies appear readily to stand trial at the fingertips of children, parents, and teachers, slower growth is seen in the development

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and maturation of our understandings of which technologies and which uses of them will be most beneficially impactful. There has been deep interest as well as concern in recruiting the power of new computer technologies in support of improved educational outcomes since well before computers were widely used. Over the course of several decades, new technologies have caused old worries to resurface (Wartella & Jennings, 2000). On the other hand, guidelines such as the joint statement of the National Association for the Education of Young Children (NAEYC) and the Fred Rogers Center (2012), address concerns about detrimental technology use: such reports clarify and raise awareness of the growing understanding that, as with non-computational materials and activities, different computer technologies fill different niches and that technology use is most beneficial when used as a means of working towards child-centered goals and as only part of a balanced "diet" of activities.

While many questions remain unanswered about the role of technology in the education of older children and adults, this is even more the case when considering young children and early education. Given their developmental traits, how do young children respond to new technologies differently from older children? How do these technologies interact with learning, social, and physical growth and development? How should new technologies for early education be designed, implemented, and evaluated? And which types of learning are best supported by particular types of designs or uses of technology?

Answering such questions requires mature theoretical frameworks for defining the salient characteristics of educational technologies, models of the relationships between technology and learning, and systemic methods for investigating and building the requisite knowledge. However, the underlying theoretical frameworks, models, and research methods for understanding and studying educational technologies with young children are only somewhat gelling, and at a markedly different pace than the burst of technological innovations. This is a second reason why it is a particularly interesting time to be in the field of educational technologies. It is a relatively new area of study stemming from the blending of both new and relatively more consolidated domains. But just what is meant by the study of educational technologies? This term is immensely broad; therefore, it is necessary for researchers to define their work within a particular subdomain of the field, based on the type of technology or the type of learning process or outcome of interest. Even so, the pertinent variables are certainly numerous but not clearly defined individually or in their interrelationships. Research approaches to educational technologies for young children share many similarities with non-technology based educational research; on the other hand, research design considerations common to newer fields also tend to come into play. The particular technological and learning goals of a

research investigation will direct the choice of an appropriate methodological approach.

This chapter overviews a range of research designs that are useful to the study of technology with young children. These methods are described and discussed in terms of how researchers might select particular methods depending on the given research goals and the clarity of the variables under study. As a promising research approach for the study of educational technologies for young children, the design-based research (DBR) approach is presented in more depth. The methodological choices and steps of one such a program are presented and discussed as an illustrative example.

### METHODOLOGY OPTIONS IN THE STUDY OF TECHNOLOGY WITH YOUNG CHILDREN

In approaching the study of educational technology with young children, a range of methodological approaches could be employed. This chapter focuses on those within the educational research tradition. There is important debate among educational research and policy communities regarding which methodologies are acceptably rigorous and lead to valid and useful findings. Opinions differ greatly on whether and how methodology standards from the physical and life sciences can be applied to educational research, a social science. For instance, beyond arguing for adherence to principles for advancing knowledge in a rigorous and systematic fashion, the National Research Council argues for a research trajectory that aims toward large-scale, randomized, controlled studies to evaluate the efficacy for improving learning outcomes of educational interventions that have undergone substantial formative testing and refinement (Shavelson & Towne, 2002). Almost on the other side of the spectrum, the learning sciences community advocates for a more local and fluid methodology: design based research (DBR). Each of these, and other, approaches has its strengths and may be best suited to different research situations. Thus, a study's methodological design can be chosen based on the type of research question and the clarity with which relevant variables can be identified and defined. The outline here follows the categories presented by Shavelson and Towne (2002), although this chapter takes a broader view on what constitutes rigorous and useful methodologies from a theory-building perspective.

#### Descriptive Methods

Not only are new technologies for young children rapidly evolving, rates of technology use by young children are also changing. This makes

descriptive studies of technology use by young children at home and in schools an important focus of study. Most broadly, researchers might set out to know what technology use looks like at the population level. What portion of a population uses technologies? Are there systematic differences in who has access and who does not? What types of technologies are used? How frequently? For what duration? What opinions do people of different ages have about the impacts of technology use? Answers to these questions set the backdrop for studying children's encounters with educational technologies at school. The Pew Internet and American Life Project at the Pew Research Center and the Joan Ganz Cooney Center at Sesame Workshop are two organizations that conduct survey research to answer such questions. Note that findings from such research may include both description of characteristics of a population and also correlational, rather than causal, relationships between or among identified factors (Shavelson & Towne, 2002). For instance, through the work at the Pew and Cooney Centers, we know how readership levels of print and e-books are changing (e.g., Rainie & Duggan, 2012) or how much time a typical six year old spends in front of a screen daily (Gutnick, Robb, Takeuchi, & Kotler, 2011). These examples focus on technology use at home and across contexts; they also cover a wide range of ages. Other work might survey schools to document what kinds of technologies schools acquire, how often these tools are actually used and for what types of activities, and corollaries of access and use.

Another category of descriptive educational research focuses on localized educational settings. This approach is used when the research goal is to build a finely granular understanding of a particular setting that is not yet well understood (Shavelson & Towne, 2002). Such a study might be undertaken to model the characteristics of a setting that is functioning other than as would be expected based on what is known. The setting might be in need of intervention or be a model for replication, but either way, if more information is needed to understand the local phenomena and form a basis for recommending and taking effective action, a localized descriptive study is in order. Mimi Ito, a technology and media researcher who classifies herself as an ethnographer, has built up a framework for thinking about young people's new media use through localized descriptive studies on the expressive and innovative uses of new media by urban teens (Ito, 2009).

In general, descriptive studies add knowledge to a field about what is happening. To move beyond capturing description and correlational relationships, towards understanding systemic and causal effects, a research study will make extensive use of detailed and often qualitative data, but it will also need to go beyond description in terms of overarching methodology (Shavelson & Towne, 2002).

### Systematic Effects

In studying causal relationships, experimental (randomized) and quasi-experimental (non-randomized) research designs may be employed because the constructs of interest are well enough understood to be clearly operationalized as variables. It is impossible to produce valid results, for instance regarding the effects of different types of technologies on a particular learning outcome unless meaningful categories of technologies have been defined, the learning outcome can be measured validly, and the instructional programs have been vetted through formative evaluation as well. This type of research can indeed lead to systematic advancements in the field of educational technologies and research. Yet, herein lies one of the challenges of conducting research on technologies for young children. Current categorization of the features of technologies and their uses is relatively coarse, and learning outcomes are not necessarily simple to pin down either.

Although technology research is moving beyond simple comparisons of learning a given topic with and without computer use, much work remains in teasing apart the relevant features and characteristics of technology that are likely to affect learning in different domains. Nonetheless, interesting and important research often proceeds with the caveat that the variables are less well understood and less clearly defined as would be ideal. Such research might estimate causal relationships, or it might take a close look at how or why observed phenomena are happening.

### How or Why Is It Happening?

Especially important to educational research are answers to questions about how or why a particular intervention works so that it might be adapted and replicated for other areas of learning or learning environments. This type of investigation must go into great detail over the course of the learning or intervention to capture and attempt to model the mechanisms driving observed change. In addition to methods such as the pairing of qualitative observations and interview data with an experimental or quasi-experimental design, studies testing the role of several plausible factors can be useful (Shavelson & Towne, 2002). If there are no strong grounds for hypothesizing one or more main factors, methods such as case studies, microgenetic analysis, and design-based research can gather more information and support the building of a plausible model to test.

The methods presented so far are tools for structuring individual studies at particular junctures of a longer research investigation. A research program may in fact make use of many of these methods as the findings from one study inform the structuring of those to come. Some argue that the overall flow of a

research investigation must be towards large-scale experimental studies with randomized controls. However, as has been discussed, educational research, including the study of technology with young children, has an inherent level of complexity of factors that make it difficult to authentically isolate variables in the way that randomized controlled studies call for; this complexity cannot be simply be brushed aside. The design-based research approach, a perspective for constructing the flow of studies with a research investigation, aims to incorporate rather than ignore this complexity.

### DESIGN BASED RESEARCH

Allan Collins (1992) and Ann Brown (1992) pioneered the notion of “design experiments” or “design-based research” (DBR) with the aim of bridging the unfortunate disconnect between education research and classroom practices. The paradigm has been taken up over the last two decades in contrast to the movement focusing on randomized control studies and in response to the recognition that educational research must be both rigorous and directly and immediately applicable to classrooms, teachers, and school systems (Barab, 2006; Barab & Squire, 2004; van den Akker, Gravemeijer, McKenney, & Nieveen, 2006). Using a “highly interventionist” approach (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003, p. 10), design-based research seeks to build learning theory with usable implications for classrooms by both designing an educational intervention and also studying why the intervention works and how related learning proceeds. Design experiments “have both a pragmatic bent ‘engineering’ particular forms of learning and theoretical orientation developing domain specific theories by systematically studying those forms of learning and the means of supporting them” (Cobb et al., 2003, p. 9). Design experiments are particularly helpful when exploring how a technological innovation affects learning and educational practice (diSessa & Cobb, 2004) and can serve as a model or test-bed for broader educational reform. Design-based research also brings the development of learning theory squarely into the complex environments where learning occurs: classrooms—although a design-based research program might also study factors that influence learning through higher levels of school organizations (Cobb et al., 2003). Through intervention and in-context study, DBR strives to contribute to education theory in meaningful and practical ways, simultaneously improving learning tools and outcomes for current teachers and students (Barab, 2006; Cobb et al., 2003).

More of a framework or a collection of approaches than a specific methodology or standardized protocol, design-based research refers to investigations that share a number of core overarching principles (Cobb et al., 2003). In a DBR program, the research question is framed to “directly address a

local problem” (Barab, 2006, p. 155) and build a local instructional theory, a term which highlights the contextualized nature of the learning theory being investigated and developed (Gravemeijer & Cobb, 2006). The local problem and evolving local instructional theory should have theoretical and practical implications in a broad set of contexts—other classrooms or schools serving a similar demographic. The investigation, in general terms, aims to understand a topic of broad interest, such as improving middle school students’ understandings of data representations and statistics (Gravemeijer & Cobb, 2006) or engaging students in educational opportunities to foster personal and moral development (Barab, 2006). However, the factors influencing the specific study include the particular classroom and student characteristics. For instance, the students bring a specific set of prior knowledge and preconceptions to the intervention, which might shape the curriculum or activity structure; additionally, researchers may be interested in assessing the impact of a particular type of intervention, such as an interactive data visualization software or a video game format that promotes social engagement, in the respective examples of broad topics just above. Therefore, the term ‘local’ is used in defining the problem and in laying out the (local) instructional theory as a reminder that the detailed findings of a specific investigation are contextual and that applying the findings to new contexts mandates the adaptation of the intervention and possibly also the instructional theory based on the traits of the new context. Staying with the statistics example, even if the students at two different middle schools had never been formally introduced to statistics, the mathematics and science topics taught at each school or within individual classrooms might lead some students to be more prepared to learn the new content or more prone to misconceptions.

Local in an additional sense, design-based research is conducted in close collaboration with teachers and students. Research teams are likely to be multi-disciplinary, and including significant input from classroom teachers and other stakeholders of the relevant context adds to the depth of expertise of the team. Therefore, a design or innovation, whether a technology, a curriculum or activity, a teaching or interaction style, or a change at more systemic or policy-making levels, is implemented through researcher-practitioner collaborations at the appropriate level (classroom, school system, policy-making body, etc.). While the research problem and designed interventions are highly local, analysis aims always to lead to more broadly applicable theory (Barab, 2006; Cobb et al., 2003). Sometimes theory building can be supported by taking a detour out of the complex classroom environment to conduct a focused study in a simplified—perhaps laboratory-based—learning context. If so, such interludes are used to directly inform the re-design of the intervention so that theoretical contributions from them can be re-evaluated in the authentic classroom setting. Ultimately,

given a rich understanding of a local context, it may be possible to adapt interventions and achieve similar learning across additional contexts beyond that of the local study (Barab, 2006).

As is hinted at by the term 'design' in its name, the design-based model is an iterative one. It employs cycles of intervention, analysis, and refinement of the intervention and the working theory of learning. In design and engineering fields, a problem is identified, possible solutions researched, one solution is implemented, evaluated, and redesigned until the problem is satisfactorily address within practical constraints. Similarly, in DBR, a local problem and setting characteristics are identified and an instructional theory and educational intervention are constructed. The intervention is implemented along with extensive documentation and data collection. Evaluation of both the intervention and the instructional theory takes place during and following implementation. Cycles of intervention, evaluation, redesign, re-implementation, and so on continue as is necessary to build the instructional theory or for as long as is practical. Interventions often last months, even the entire academic year or more. Iteration is paramount because DBR rests on the premise that it is not possible to understand learning within a domain by isolating a limited number of factors in an artificial setting, and iteration provides a flexible yet systematic tool for investigation (Barab, 2006).

Furthermore, given the complexity of a classroom learning environment, it cannot be assumed that all pertinent variables and relationships will be known at the outset of the study (Barab, 2006). As such, extensive data are collected at multiple levels from classroom characteristics and curricular activities to individual student trajectories. The large scope of documentation and on-going analysis allows re-analysis of earlier episodes and iterations as necessitated by the evolution of the local instructional theory (Gravemeijer & Cobb, 2006). Ultimately this analysis aims to provide evidence for a model of the factors which make that intervention successful in a given context so that others can adapt the intervention to their own settings. Ideally, compelling evidence can be presented to make the case that the local context of design-based research is a "paradigm case" (van den Akker et al., 2006, p. 43), an exemplar of the underlying learning theory which provides insights that apply to other settings. Thorough retrospective analysis of the investigation provides the evidence for such an argument (Cobb et al., 2003; Gravemeijer & Cobb, 2006).

Of great importance for showing that the design-based research paradigm is useful for generating educational theory as well as applications is the question of showing the rigor—the validity and reliability of the study or its component methods. The fundamental issue is that the traditional ways of demonstrating validity and reliability in strictly experimental designs (e.g., medical studies) inherently cannot be used in design-based work (Barab, 2006; Gravemeijer & Cobb, 2006). While it is possible to

document traditional measures of validity and reliability for certain types of individual assessments used, the same cannot be said of the overall design-based investigation due to its dynamic nature. Several authors have provided arguments for alternative definitions of validity and reliability within the design-based research framework. Gravemeijer and Cobb (2006) suggest an "ecological" validity (p. 45) which is the presentation of the relationship of important factors in the success of an intervention so other can reasonably understand what aspects of the design to alter when adapting it to new settings. They and others also suggest that reliability in design-based research may take the form of data and the conclusions drawn from them being presented in sufficient detail for other researchers to evaluate the claims and conclusions; this has been called "virtual replicability" (Barab, 2006; Gravemeijer & Cobb, 2006, p. 44). However, given the newness of the DBR approach, discussion of defining even a high-level design-based research protocol and issues of validity and reliability are ongoing. Therefore, these definitions are not yet implemented across the field as standardized methodology and publishing practices. Generally, however, proponents of DBR have argued that the paradigm works within different criteria for rigor than those for randomized and controlled studies, but that each set of definitions of rigor serves the type of research to which it applies.

The design-based research model has been proposed as an effective tool for research to use in exploring theories in the early stages of development, before the area is well-mapped with clearly defined conceptual variables (Anderson & Shattuck, 2012). DBR also allows researchers to both impact and study complex learning environments, like classrooms, with practical results (Bell, 2004). Like all methods, DBR has its limitations. To begin with, DBR studies require extensive data collection and analysis, which can pose practical challenges to a research team. Additionally, there are issues of standardization of research protocols and practices, given the high-level nature of the paradigm and its focus on the flow of studies over the course of a research program in addition to the selection of descriptive versus experimental studies. Complexity stems from the authentic classroom environment and the difficulty in validly measuring many learning outcomes—especially in new, technologically focused domains or activities. Exclusive use of measures validated to the extent common in other social sciences like psychology is difficult, because many studies investigate variables for which such measures do not exist and would take a long time to create. The topic of a design-based research study may address an entire domain—like computer science—that is not typically included in standard curricula and assessments for a particular age group; or, the study may wish to investigate an aspect of the classroom technological ecosystem that simply does not have associated standardized methods of assessment. Therefore, existing measures may not be relevant and new ones must be created. Due to

the urgency for educational research to produce practical and applicable findings, design-based research programs often proceed with measures that have not undergone the traditional process of validation or standardization. Although valuable, validation processes can take years, and researchers working with the DBR paradigm believe that effective educational interventions and applicable theory can be created in a shorter timeframe.

This section has provided a high-level introduction to the design-based research paradigm. As is typical of other DBR literature, the next section offers further illustration of the approach through a discussion of how the design-based research approach shaped an example research program, in this case the TangibleK Robotics Project. The project is conducted from the design-based perspective and has experienced many of the challenges and benefits of design-based research. It involves the iterative design, implementation, and evaluation of robotics and programming technologies, curricula, and assessment instruments aimed at understanding how to best support young children in their quest to develop competence in technology and engineering. This discussion will focus on steps and decisions made in relation to the project's design-based nature rather than delving into specific qualitative and quantitative data collection and analysis techniques, which would be more appropriate to a chapter on those specific protocols.

### THE TANGIBLEK PROJECT

The TangibleK project is an educational robotics program that has been piloted and implemented with children and teachers in preschool to second grade. It consists of curriculum, assessment tools, and a robotics construction kit with a developmentally appropriate interface. The curriculum and the robotics kit are specifically aimed at teaching young children powerful ideas and skills that are useful when applying computational thinking in a robotic context (Bers, 2010; 2012). To date, over 600 children in 6 schools, 2 museums, and over 20 early childhood teachers have participated. The TangibleK Robotics Project has consisted so far of five major iterations of studies that each helped refine the curriculum, the technology, and methods for the assessment of children's learning. What follows is an overview of the research program, the cycle of studies undertaken to date, and the reasoning and evolving research questions that have driven each iteration of the project.

#### Underlying Contextual Theories

The TangibleK Robotics Project is couched in two related and overarching theories: *Constructionism* and *Positive Technological Development* (PTD).

The constructionist theory of learning draws heavily on Piaget's constructivist theory of cognitive development and was developed by Seymour Papert (1993). Constructionism integrates the power of exploring tools and materials and building functioning objects, with a particular focus on computational tools and digital or digitally enhanced objects. Papert writes about how deep and motivating learning occurs as students make physical, functional artifacts and reflect on the relationship between design choices, the construction process, and their results (Papert, 1993; 1999; Papert & Harel, 1991). Using programming to build and experiment with digital objects engages children naturally with powerful ideas from traditional content domains, such as mathematics or engineering, as well as 21<sup>st</sup> century skills like creative design and content creation and high-level cognitive skills like complex problem-solving (Papert, 1993; Resnick, 2007).

PTD, developed by Marina Bers, builds on constructionism and provides a framework for intentionally structuring technology-focused programs and curricula so as to promote positive youth development through cognitive, emotional, social, and moral outcomes in addition to content-domain learning and technological literacy (Bers, 2010; 2012). The PTD framework provides guidelines so educational experiences can be structured to encourage content generation, creative design and problem-solving, collaboration, communication, choices of conduct, and community-building in ways that may in turn foster the development of beneficial core cognitive and social traits: a sense of competence and confidence, the ability to connect with and care about others, contribution to entities outside the self, and moral character (Bers, 2010; 2012). TangibleK researchers and teachers collaborate to tailor the robotics and programming activities to support these traits and behaviors within the participating classrooms' cultures (Bers, 2010).

As Constructionism and PTD focus on individual learning processes as well as contextual influences, it made sense to frame the study of a new robotics program within the design-based research approach to take advantage not only of its focus on iterative design but also its focus on capturing and modeling the complex factors at play in a classroom, some of them unknown at the outset of the initial study.

#### Learning Goals, Technology Designs, and Initial Hypotheses

Some work has been done on young children's understandings of robots as computational artifacts (e.g., Levy & Mioduser, 2008; Mioduser & Levy, 2010) and on their understandings of computational logic (e.g., Mioduser, Levy, & Talis, 2009; Wyeth, 2008), but there is at present still much knowledge left to build regarding how working with new technologies might promote

computational thinking in young children and what kinds of learning trajectories lead to the best outcomes. The goal of the TangibleK research program is to explore both learning and computer interface design issues with regards to young children's creation and programming of robots. Three research questions, aimed at both describing learning with robotics materials and exploring the mechanisms that drive it, are at the core of the project:

1. What are young children's learning trajectories in computational thinking when exposed to an educational robotics program?
2. What concepts and skills from robotics programming can young children develop throughout early childhood, and what support mechanisms (in terms of both curriculum and technology) do they need?
3. What design elements should a developmentally appropriate robotics kit include to engage young children in a successful learning experience?

As described in the first research question, the educational goal for children who participate in the TangibleK Robotics Project is to develop computational thinking, a broad category of knowledge, skills, and attitudes related to applying computers to solve compelling problems (see, e.g., Barr & Stephenson, 2011). TangibleK aims to teach children about the basic nature of robots—the special elements they are made of that allow them to be programmed, to move, and to sense information about their environments—as well as concepts related to programming and overall strategies for problem-solving by applying the engineering design process (Bers, 2010). To meet these goals, the project has developed an intervention consisting of developmentally appropriate programming and robotics tools and a curriculum which guides children through robotics and programming concepts with a series of problem-solving and project-based activities.

The TangibleK project took shape with the creation of a developmentally appropriate programming tool with which kindergarteners could program behaviors for robotic vehicles. The first version of the tool, Tern (Horn, Solovey, & Jacob, 2008), was a tangible set of high-level programming instructions in the form of wooden flat puzzle pieces with which children could easily build programs for robotic vehicles. Tern supports young children's engagement with robotics by separating the core intellectual process of programming from the physical and incidental cognitive processes of typing out low-level instructions (Horn, Crouser, & Bers, 2011). As Tern was used with elementary school-aged children the researchers came to understand the potential for adapting TERN to become an even more developmentally appropriate tool for young children; the wooden flat puzzle pieces became wooden blocks, and the blocks' labeling system evolved, among other changes to the programming instruction set (Bers & Horn, 2010).

Over time, Tern became CHERP, which has a hybrid tangible-graphical interface, meaning that children can make their programs on-screen or with the physical blocks and switch between the two as they wish. This choice reflects the idea that, when given the option, children choose which interface to use in a fluid way, based on a number of factors beyond physical ease of use. Figure 8.1 shows an example of a robotic vehicle built from the LEGO® WeDo™ construction kit along with a tangible CHERP program.

The TangibleK Robotics Project has spent over five years uncovering what kindergarteners can understand from the domains of computer science and robotics and how their learning progresses as they engage in activities with these developmentally appropriate tools. A second and crucial element of the robotics project is the development of interdisciplinary curricula. Each activity in the TangibleK curriculum introduces a core idea of computer science that is tied into other curricular domains (Bers, 2010). Children plan, create, test, and trouble-shoot a robotics and programming challenge in each activity. The activities encourage problem solving and collaboration rather than competition and efficiency. Holding competitions is a common approach to robotics in K–12 education today, but it is avoided in the TangibleK curriculum because, while competition engages some students, it intimidates others, particular girls (Bers, 2012). Following the introductory TangibleK activities, classrooms further explore, integrate, and demonstrate their knowledge by taking on a self-selected final project. Each teacher chooses a theme for the final projects that reflects a topic that

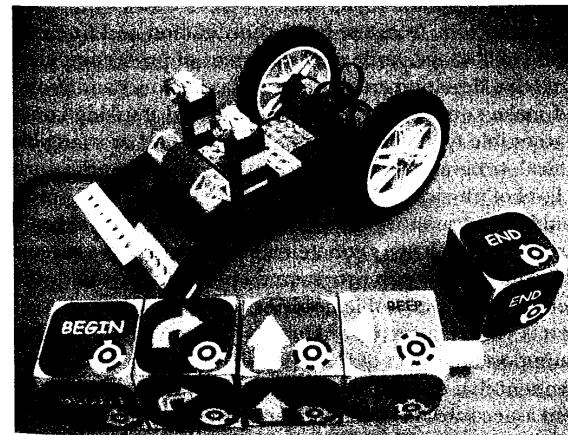


Figure 8.1 The CHERP Tangible language and a robotic car.

the class has been studying or is otherwise interested in. Then, each child decides on a particular project within that theme.

Classrooms have carried out projects related to diverse themes: animal behaviors, transportation and vehicles that help around the community, maps, and concrete representations of each child's metaphorical journey through the school year. For instance, for the theme of animal behaviors, children decorated robots to resemble snakes, cats, rabbits, and more, and created programs for these robotic creatures to slither back and forth or to come out of their construction-paper homes only in the dark. In classrooms that focused on vehicles and transportation, children built helpful community vehicles like snowplows and recycling trucks. They programmed these vehicles to follow pathways on a large floor map of the children's community. Another group was learning about the Iditarod dogsled race. They created a large floor map of the race and recreated the original relay race with robotic dogsleds. One of the most extensive projects teachers have undertaken was called "Who Am I?" In this end-of-year project, children created robots that represented themselves and programmed the robots to travel along a timeline of important events from the school year. At three child-selected points on the timeline, the robot stopped and carried out an action or behavior that represented the event or the child's reaction to the event (Bers & Ettinger, 2012). Projects such as these allow students to continue exploring the core computational and robotics concepts at the core of TangibleK curriculum while also integrating content from another domain of interest to the class. The projects also allow for differentiation as students can select a project scope that is well suited for their level of expertise.

The TangibleK Robotics Project started with an initial hypothesized model of important factors, from eye-hand coordination and fine motor skills to sequencing ability, age, and type and extent of prior computer use. We hypothesized that developmentally appropriate robotics and programming tools could make core concepts of computational thinking concrete and therefore accessible to young children. We thought that a tangible, rather than graphical, programming interface was most appropriate in terms of children's level of physical development and that the more appropriate interface would better support children's learning. Finally, we hypothesized that using a robot, which gives concrete feedback about the success of each attempted solution to a given programming challenge, would support the development of iterative problem-solving strategies and other high-level skills related to computational thinking. As a design-based research investigations, an important aspect of the TangibleK research framework was the acknowledgment that our initial model was likely incomplete and that other important aspects would become clearer as the investigation progressed.

Before turning to a discussion of the progression of design experiments that comprise the TangibleK Robotics Projects, we first discuss our

techniques and general experiences with the documentation of data and its interpretation.

## Methods

Given the broad and evolving foci of the project, drawing from a variety of research techniques allowed us to gather and analyze data with which to refine our theoretical understandings at each point in the project. We collected both broad and targeted data: prior related experience, demographics, conceptual understanding and achievement, user interface preferences, and teachers' and parents' feedback about on program. We studied issues of teaching and learning robotics and programming in early childhood from the classroom level and whole-group patterns down to individual children's progress in the detail of a case study or microgenetic study. Some of the challenges we encountered include balancing the collection of detailed information with time constraints and other practical limitations and, significantly, the lack of existing validated relevant measures in the literature on young children developing computational thinking and robotics knowledge.

## Gathering Data

The main goal for general documentation is recording sufficiently detailed information so the research team can accurately re-experience the episode for coding and interpretation at a later date and so that, for evaluation of validity from the DBR perspective, other researchers can assess the initial interpretations of the data. The broad scope and high level of detail of the data are crucial because, in line with most design-based studies, the TangibleK Robotics Project aims to understand relevant processes of learning which are complex and nuanced. Learning and developing new understandings are also phenomena that occur internally within the minds of participants, and researchers must attempt to bring to the surface observable indicators of learning and understanding. This adds to the challenge of developing valid measures. A secondary goal of documentation is to record initial reflections on important features of the episode so preliminary interpretations of it can be subjected later to more systematic analysis.

The TangibleK program has made use of high- and low-tech recording and documentation techniques from pen and paper to video and screen capture technologies. Often these techniques complement each other. The predominant mode of data collection varies with the research setting (classroom, out-of-school enrichment program, or laboratory) and with the study goals. For instance, having an observer taking old-fashioned notes guided



by a protocol remains a useful means for recording information that may not appear clearly in video or audio recordings—subtle gestures and facial expressions or quiet utterances by the study participant. These notes can also include initial interpretations and questions prompted by the observation. For more systematic understanding of entire activities, both video and audio effectively capture a large portion of the study episode. Audio recordings may work sufficiently for assessments that are entirely conversational, that is, assessment situations in which the child's manipulation of the robotic parts, the programming interface, or other materials was not important data itself.

Video recordings are useful for several data collection purposes. Video-format data is indispensable for materials-driven activity if any interpretation or analysis of the learning process will take place at a later date. First, video footage gives context to conversation between researchers and children if it is possible to see exactly what the child is working on or doing with the technology. Second, video documents non-verbal communication—facial expressions and other body language—which may be important for understanding the child's experience and learning process, especially in the case of young or shy children who may be very expressive though not necessarily verbally articulate. Additionally, since data storage is increasingly affordable, it can be easier to record and manage video than plain audio.

The main benefits of video—documentation of technology use and non-verbal communication—create a technical challenge: capturing the right footage. In one-on-one work with a child and the TangibleK robotics and programming technologies, we ideally capture three areas: the child and his or her expressions and actions, the content of the computer screen as the child works, and the physical materials (the tangible programming blocks and the robot). It is not possible to capture all three with one camera, and it is time-consuming to work with multiple videos of each session. Video capture in a classroom also poses challenges in determining how to focus on one area closely enough to see what is happening while also maintaining some record of the whole-group experience. These issues can be addressed in several ways, although none is entirely mitigated.

Built-in software logs have the potential to provide more compact data than videotaping. In TangibleK, logging is built into the CHERP software such that basic information is documented each time the child transmits instructions to a robot—the program, the interface used to create it, and a timestamp. While this does not provide data to answer *why* or *how* questions, it provides a succinct data set to describe a slice of *what* children did over the course of the intervention, an important precursor to answering *why* or *how*. We also use software such as Camtasia Studio® that goes several steps further and offers the ability to acquire video screen capture while one or more webcams document the child and/or the materials they are

working with. Although such software tools still may not capture an entirely complete picture of the activity and the child's learning process, they do get much closer than individual video cameras can. Furthermore, some video-capture packages also include useful tools for synchronizing, coding, and editing multiple feeds.

Finally, we find that video is a successful format, compared to writing, for teachers, parents, and students to document summaries of and reactions to the robotics program. Video is an especially appropriate format for children to demonstrate their robots and programs in action, which writing and photographs can only partially do. Since most of the children in the TangibleK Project have only budding writing skills, video can efficiently record what children say about their robots and the process of creating them. Teachers and parents are also able to quickly articulate their thoughts and feedback in a natural conversation with a researcher. (We do provide opportunities for adults related to the project to offer anonymous feedback online as well.)

We have found that a few key points influence our use of interview and questionnaires. As mentioned, interviewing has been an effective tool for documenting feedback from adults involved in the study and children's statements about their projects and general understandings. We also typically use interviews and open-response questionnaires for participants to supplement and expand on corresponding Likert scale items. In short, the overriding issues are two-fold: Do subjects interpret questions as intended? And, are (especially young) subjects able to reflect on and articulate the concepts of research interest? Depending on the expected answers to these questions, we must design the study and our data collection techniques to best gather the information of interest in a way that works well for the participants and is likely to result in data that are valid representations of the variables we intend to measure.

When studying early childhood, documentation of the learning episode and its processes is of particular importance because young children are relatively less able to articulate their thinking processes than older children or adults, and they are less likely to later recount their experience in the kind of accurate detail that a researcher needs. Therefore, it is crucial for researchers first to structure activities in such a way that thinking processes and understandings can be observed and second for documentation to be thorough enough to adequately revisit the study session.

One of the major challenges we have faced in conducting design-based research is the nature of collecting data in a classroom setting. A general challenge is that of documenting the experience of individual children and the whole group simultaneously. This can be mitigated somewhat with screen-capture software as discussed earlier. It can also be simplified by looking for case study examples from within the entire class. A second challenge

that influences our data collection as well as how we design our measures is that a teacher can only devote so much time to research activities. Student interviews or detailed baseline assessments may yield the most meaningful data, but at times these must be used strategically or streamlined to accommodate data collection from a larger group of children.

By focusing data collection on both high-level and detailed variables, we have been able to put together an increasingly detailed picture of diverse variables such as background information and experiences, baseline cognitive skills, achievement outcomes throughout the curriculum, learning processes within activities, post-intervention changes in baseline assessments, and some of the relationships among these factors. We also specifically set out to collect more data than we initially planned to analyze because we knew interesting questions would arise along the way and it would be crucial to be able to re-analyze the existing data set in an attempt to answer them. As we learned, it can be challenging to collect this extra data in a way that provides sufficient detail for re-analysis. Frequently, the questions of interest require conversation with the children to get at their ideas, although sometimes variables of interest can be measured by observing video footage of the relevant episodes. Despite the limitations of re-analyzing data collected for other purposes, even preliminary retrospective analyses can provide justification for systematic investigation of these new questions in a new study.

### Coding Schemes and Interpretive Frameworks

Data collection, for all its logistical challenges, is usually the easy part. In the areas of robotics and programming, especially in early childhood, there are very few standardized conceptual variables or measures. Those that do exist are for better understood domains, such as aspects of cognition, rather than for understanding of robotics and programming concepts. Furthermore, the possible variables of interest are only loosely linked in a web of probable relationships. There is a lot of rich content to research and few standardized tools to do so. The dilemma of the researcher is to proceed with relatively new measures and interpretive frameworks or postpone investigations of practical interest and import to conduct extensive validity studies. The design-based research literature urges rigor in the selection and implementations of research methods and simultaneously prioritizes practical results. One strategy the field has developed is to detail the research intervention, data collection methods, and interpretive frameworks as precisely as possible so that other researchers can evaluate for themselves whether the methods and findings are satisfactorily rigorous and reasonable (Gravemeijer & Cobb, 2006).

Of course, some of the cognitive variables we are interested in (e.g., cognitive development, various forms of executive function) have been extensively studied and valid, reliable measures can be found in the literature. This is not the case for variables related to achievement in robotics and programming at the early childhood level—these variables are largely undefined, let alone integrated into validated measures. Therefore, as we iterate through revisions of the technologies and curricula, we also refine our own assessment tools and measures for these measures. In other cases, existing validated assessments are too time-consuming to administer to a whole class or grade in their original forms, and we must carefully pare down the assessment to our specific focus without losing validity. For the most part, however, our data coding work focuses on the development of new assessment tools related to robotics and programming variables.

For instance, a major set of measures in each TangibleK study pertains to children's achievement or learning of the core elements of the curriculum. These range from the basic components of a robot and their functions to using sequencing to arrive at a programming goal to applying the engineering design process. In each study, researchers observe children as they work (and interact with them as the children have questions or need support and as is otherwise appropriate to establish a socially comfortable setting). The researchers are tasked with documenting the extent of children's learning of several specific skills or concepts at the end of the session. The particular skills and concepts as well as the coding scheme for measuring learning have evolved significantly over the course of the TangibleK Robotics Project. As the study progressed, for instance, we developed a more connected model of how concepts are related, allowing us to eliminate superficial concepts and focus on the core ideas. The coding schemes continue to evolve.

The first classroom studies used a simple, 3-point achievement scale based on how thoroughly the child was able to apply or demonstrate each concept or skill—not at all, partially, or wholly—by the end of the class session. This was adapted for subsequent study and expanded to a 6-point scale. This study involved children working one-on-one with a researcher, allowing a finer granularity of data to be documented. The protocol included a given period of the child working independently, after which the researcher gave whatever degree of help was necessary for the child to accomplish the task and gain the embedded understandings. The degree of help was documented as a measure of the child's learning process since, theoretically, given the researcher's help, all children would reach at least a baseline level of understanding by the end of the activity. This coding scheme was impractical to export back to classroom settings due to level of adult involvement required per child and the highly structured sequence of work periods and assessment points. Therefore, the scale and the assessment protocol were revised to include fewer—but well defined—points on the scale and to be feasible to implement

with or without the child present at the end of the session. The skill and concept measures are now each assessed by looking at the products the child has made: a robot and a program of instructions. This strategy prevents the need to closely observe each child over a prolonged period of time or to necessarily discuss their work and ideas with them to obtain the measures. Such requisites for accurate data collection would be quite impractical with a classroom setting and twenty or more children but comparatively very few adults. Even with screen-capture software and webcams, if the researcher will likely need to ask every child to clarify his or her intentions and ideas, the measure is not likely to be successful.

Other variables, such as those related to the child's process of troubleshooting unexpected intermediate results, inherently measure processes and cannot be distilled to final products. We continue to work with our measures and data collection techniques for documenting such variables in a classroom. Currently, we make general observations of the entire class, collect screen-capture and webcam video, and then select a few students to work with individually for more detailed documentation and build case studies that exemplify regular patterns. We then are able to compare, for example, how a child's problem-solving trajectory aligns with or varies from the engineering design cycle.

To reach the high-level goal of the TangibleK Robotics Project to outline the learning trajectories young children follow as they gain experience with robotics and programming materials and activities, we have created the several iterations of coding schemes described above. An important aspect of this work is to look back at existing data to see if a new version of the coding scheme makes sense across many children's data. This strategy of retrospective analysis is crucial, since in each study, we encounter as many new questions as we may answer—if not more! Re-examining data with a new lens lets us see whether it might be useful to add another measure to our next study, to design a new study altogether, restructure the next study to collect better data on a particular variable, or redesign our technology, curriculum, or assessments to test a new hypothesis of the learning trajectory and learning ecology.

Having presented a discussion of the data collection and coding issues pertinent to the TangibleK Robotics Project, we now present the course of the project as series of studies guided by the design-based research approach.

### Design Experiments

Over more than five years, the DevTech Research Group at Tufts University has implemented a series of studies to refine our understanding of young children's learning trajectories as they use developmentally

appropriate tools to engage in computer science and robotics. Over the course of the project, children with a wide range of technology-related prior experiences have participated, from children who used no computer technology at home or school to those who were already familiar with the robotics hardware from after-school programs at their schools. Children in the target age range (roughly 4–7 years old) also spanned a wide range of levels of cognitive development and high-level thinking skills such as sequencing and categorization. Thus children had quite different cognitive or reasoning skills at their disposal for solving the complex problems faced in the TangibleK curriculum. The TangibleK studies have taken place a range of contexts, from public and private elementary schools, to museums, summer enrichment programs, and in the research lab itself. Each study has employed mixed methodologies and data collection techniques to paint a detailed picture of the phenomena of interest and fill gaps in the working model of what and how young children learn about robotics.

### Study Phase 1

To summarize the starting point of the TangibleK studies, recall from earlier the overarching the research questions. What are young children's learning trajectories in computational thinking when exposed to an educational robotics program? What concepts and skills from robotics programming can young children develop? And, what design elements should a developmentally appropriate robotics kit and curriculum include to engage young children in a successful learning experience? It was hypothesized that the physical Tern interface would support robotics learning and computational thinking better than a graphical interface, and that physical, cognitive, and experiential factors would cause differentiated learning outcomes among children exposed to the same technology and curriculum.

With these initial research and intervention designs in place, the TangibleK studies began in the kindergarten classrooms of a public elementary school and a museum. Researchers implemented the TangibleK curriculum with the tangible Tern programming language at the public school. This provided preliminary and basic feedback about the feasibility of using the technological and curricular interventions in the classroom and expected student responses. It also introduced the research team to salient issues of classroom implementation that might need to factor into the curricular or technological designs. At the museum, a hands-on exhibit provided children with the opportunity to play with both tangible and graphical versions of the programming environment. For visitors who participated, information was logged to look for such patterns as who chose each interface and

how long they spent with it to better understand the impact of the interface type on engagement with a programming activity (Horn et al., 2011).

### Study Phase 2

Next, a second and more controlled comparison study was designed, incorporating the findings from the initial exploratory and descriptive studies at the museum and an elementary school; this study also returned from the museum to the school setting. Four new kindergarten classes were taught the same TangibleK curriculum, two using the tangible version of Tern and two using the graphical version. Children's work during each session was assessed for the demonstration of understanding core programming and robotics concepts pertinent to that activity. The robotics lessons included concepts such as sturdy building and robotic parts for motion and sensing, while programming challenges included matching programming blocks to intended robotic outcomes and sequencing. The purpose of the study was to compare students' learning and achievement with each of the interfaces (Horn et al., 2011). However, the study led to the unexpected realization that, in fact, a hybrid interface—one which integrates both graphical and tangible elements—could be more beneficial than either tangible or graphical interface alone, as it supports multiple ways of representing ideas (Horn et al., 2011). The technology was revised to provide such a hybrid interface. Analysis of the intervention led to the observations that the curriculum and assessment tools needed revision as well. The curriculum was adapted to ensure that the level of difficulty of each activity was appropriate, and the individual learning assessments were updated to include a more granular scale. As with each subsequent stage of revisions, the revised intervention designs underwent formative and pilot testing with children during the summer. During initial testing of the hybrid interface, new research questions arose about how children respond to the choice of interfaces.

### Study Phase 3

Following the pilot evaluation of the hybrid interface, a third study was conducted, this time in the DevTech laboratory. This in-depth study of individual children's learning processes focused on several new research questions as well as specific portions of the original overarching research project. With regard to interfaces: Why do children choose one interface over the other when given the choice? Why and when do they switch between them? It was hypothesized that motor skills and familiarity with computers

would influence interface selection. We also wondered: What core concepts are children learning well, and what concepts pose the most common roadblocks to learning? From the original classroom studies, some learning outcomes were not as clearly understood as we wanted, therefore, in-depth documentation of learning was conducted the laboratory study. Finally, how can the technology and curriculum be (re)designed to support the challenge of learning to program robots? Such questions, which often required answers on an individual child level, were difficult to answer clearly in the complex and social setting of a classroom. Because the field of early childhood robotics and programming is complex and yet relatively unstudied, we needed to establish some basic understandings about how children think and learn within this area on a detailed and individual level and about how features of these thinking patterns interact with the features of the technology and curriculum to support or hinder learning.

During the individual-level study, we collected background information such as parental involvement in science, technology, engineering, and math fields, children's and parents' prior experiences with computers, robotics, and programming, and whether children lived in an urban or suburban area and attended a public or private school. We recruited older preschoolers as well as kindergarteners so the sample would include a range of ages and abilities with the aim of supporting our documentation of learning trajectories through the robotics and programming concepts. Children in the study completed baseline assessments on fine motor skills, basic reading, picture-story sequencing, and giving instructions. They were taught in small groups how to use the robotics and programming tools and had some time to explore and make any programs they wanted. Then, each child completed three individual sessions in which the child reviewed familiar content, built a robot, completed a programming challenge, and reflected on the understandings built during the sessions. In the final session, children repeated a second version of many of the baseline assessments. All along the way, researchers documented achievement of many programming concepts and noted any other observations that seemed to warrant additional attention. Simultaneously, the programming software logged which interface—tangible or graphical—children had chosen each time they programmed their robots (Horn et al., 2011).

Analyses stemming from this study variously compared children's learning outcomes on introductory, intermediate, and advanced activities, including microgenetic examination of children's reasoning and learning, compared pre- and post-assessment scores, and looked for correlations between learning approaches and outcomes and a wide range of background factors. This extensive set of analyses led to some interesting findings—such as an observed increase in picture story sequencing scores following

the intervention (Kazakoff & Bers, 2011)—as well as evidence for redesigning the technology, curriculum, and assessment tools.

Technology designs were influenced in two major findings of this study. First, the hybrid nature of the CHERP interface was solidified since different children had shown preferences for each based not only on physical ease of use but also on a socially constructed appeal factor. The ability to switch interfaces also seemed to support many children in their problem solving and debugging. Second, it became clear that the robotics technology needed to be as developmentally appropriate as the programming language. At the time of this study, we were using a robotics construction kit that was designed for much older children. It had a number of finicky aspects that added too many variables for young children to track in trouble-shooting their programs. This led to a decision, now in progress, to develop a low-cost, developmentally appropriate robotics hardware kit that works with CHERP.

Other findings influenced learning goals and curriculum design. For instance, evidence was found that learning expectations and curricula should be differentiated for children within the target age range based on their level of cognitive development. While nearly all the children found the robotics and programming materials to be exciting and intriguing, children with developmentally different approaches to reasoning tend to use the materials in different ways. Younger children use the time to explore the process of programming their robots and observing the outcomes to become more aware of the causal link between the robot's actions and the instructions and their sequence in the program. Older children more readily define and pursue a specific goal or outcome for their programs. Because of this finding, we now differentiate curricula for preschoolers and younger kindergarteners from curricula for older kindergarteners or first graders. When working in new classrooms after this study, we have encouraged teachers to provide plenty of open-ended exploration time to meet the range of needs of the children in the class. We also found that the intermediate and advanced activities were significantly harder than the basic activity. Although we knew this would be somewhat of an issue in the condensed curriculum used during the individual-level study, the findings warranted changes to the full curriculum. In short, children needed to spend more time on each concept, particularly early ones, before they moved on to harder ones.

Finally, this study led to adaptations of assessment methods, which were already slated for revision and streamlining for feasible future classroom use. However, our analysis of data from the expanded assessments led to the clarification of the variables of interest in each activity, the relationships among them, and ideas for measuring them as concisely as possible.

#### Study Phase 4

The fourth study phase was conducted within four kindergarten classes at two different schools, one public and one private. Here, once again, we looked at student learning in a classroom context, but this time with a more trained eye. In these classrooms, teachers, rather than researchers, taught the curriculum so that we could uncover aspects of the intervention that would need further adaptation to be reasonably usable by average teachers given their training and resources. Analysis of this study uncovered nuances in findings from the laboratory study, such as a fuller categorization of relatively easier and harder concepts for kindergarteners to learn. Subsequently, we have split the curriculum into two units: one entirely devoted to exploring and sequencing actions, and one which adds the complexity of control flow and sensors. The data collection from this phase also opened up the possibility of exploring new questions, like gender differences (Sullivan & Bers, 2012).

#### Study Phase 5

Finally, during the fifth study phase, the curricular interventions were adapted according to the knowledge gained during phases 1–4 to transfer the robotics program to a new context. This phase was conducted at a new school, a diverse, inner-city public magnet school undertaking a multi-pronged technology-focused professional development and integration program, of which our study was one part. At this school, which serves grades preschool through two, we worked with teachers and administrators to adapt the full curriculum to topics under study in preschool through second grade classrooms and to the learning needs of each grade. Teaming up with the school's staff as well as university students enrolled in a technology education course, researchers implemented a week-long intensive robotics program. By the time of this study, a new robotics construction kit aimed at children ages seven and up had become commercially available, a certain improvement over the kit for older children used in prior studies due to a lack of other options. All grades at this school had access to the new kit. The second graders, being above the target age range for TangibleK, also used a more advanced programming tool. In terms of data, baseline and post-intervention data documented changes in children's sequencing and composition assessment scores. Learning achievement was documented in each activity and after culminating student-select projects; analysis is ongoing. At a higher level of evaluation appropriate to the goal of adapting the TangibleK robotics program at a new context, the school's teachers and staff reported that the robotics week built excitement about robotics and

programming among students, parents (who were invited to a show-and-tell event on the final robotics day), and the teachers themselves. The teachers also felt that both they and the children had made very reasonable gains, for a first in-depth exposure, in their knowledge of and comfort with using robotics and programming technologies into early childhood education.

### TangibleK In Sum

The TangibleK Robotics Project has passed through multiple phases of study, from preliminary descriptive endeavors to more systematic investigations in both classroom and laboratory settings. Using the knowledge iteratively gained in these varied contexts, the Project has led to the refinement of a programming technology (CHERP), the adaptation of a curriculum to a variety of content themes and different age ranges, the creation of learning assessment tools that are feasible to implement in classrooms and informative for research, and the expansion of understandings regarding children's learning processes in robotics and computational thinking, as well as how that learning can be influenced by individual and contextual factors.

Today, studies continue through implementation and refinement of the program in still more classrooms and by examining in further detail variables which have proven particularly complex and interesting in building a detailed theory of children's learning of robotics, programming, and computational thinking. Noted earlier, for instance, was the finding that cognitive development seems to play a mediating role in children's programming approaches and achievement levels. We have examined how to differentiate learning expectations to support children whose reasoning is intuitive versus concrete operational, and we are conducting follow-up studies to confirm and extend these findings. We are also re-examining the circumstances under which children choose or change interface type during an activity period with the hypothesis that socially-mediated appeal ('coolness') of the interface, physical development (eye-hand coordination and fine motor skills), and problem difficulty may all contribute. As previously mentioned, we are embarking on a new project to design a robotics construction kit specifically for early childhood, to be paired with the CHERP programming environment. Finally, we are in the process of developing a learning trajectory about how young children (5 to 7) progress through learning the powerful ideas of computer science embedded in the curriculum. This theoretical contribution will further inform the design of new curriculum and new technological innovations.

The TangibleK Robotics Project followed a design-based approach, iteratively refining and evaluating both educational interventions of practical value to classrooms today and theoretical knowledge of young children's

learning of robotics, programming, and computational thinking. As the cycle continues, this knowledge can be used to adapt the existing technologies and curricula to new learning contexts and to design new technological interventions, even as new knowledge is also constructed.

### CONCLUSIONS

This chapter has presented an overview of study methodologies relevant to the study of technology with young children, their purposes and some strengths and challenges offered by each. Discussed in more depth was the high-level design-based approach to conducting investigations, which seeks to bridge the gap between theory-building research and practical, effective classroom solutions. A discussion of the TangibleK Robotics Project was included as an example of DBR, including data collection and coding methods useful to study educational technologies for children in preschool through grade two as well as the flow of research questions from each study phase to the next. We have also discussed the main benefits and challenges we see in working with various methodological tools to conduct research with technology and young children.

Recall the race between the tortoise and the hare. Once upon a time, these fabled creatures surprised themselves and their acquaintances by demonstrating how intermittent bursts of speed and measured pacing sometimes yield similar forward progress over time. Though their approaches in reaching a common end-goal differed, the characters' achievement, over enough time, was comparable. Today's researchers who explore the design and implementation of new robotics and programming technologies in early childhood education face something akin to the tortoise and hare mid-race—technologies are far outpacing research methods.

Educational technology researchers come from diverse backgrounds—engineering and human-computer interactions to education, child development, and cognitive science—yet share a common high-level vision of effectively designed technologies expertly integrated into learning environments so as to support educational engagement and outcomes. However, the volume of intriguing new technologies and models for how to use them to improve education overwhelm the consolidation of research methods with which to conduct systematic primary research and program evaluations. It is as if the technological hare has burst out of the starting gate and the methodological tortoise has had insufficient time to catch up. Fortunately, the larger portion of the race is left to run.

Both technical and educational areas have plenty of innovations yet to make. One of the core challenges of studying technologies within learning contexts today lie in the refinement of methodologies, such as design-based

research, that can lead to broadly applicable findings and theories based on the study of how new technologies can impact complex settings like early childhood classrooms. Another challenge lies in the related challenge of creating mature frameworks with which to gain perspective on novel problems in educational technologies for children. Ultimately, the research methodologies used in educational settings to develop rigorous theory will progress, as will the theoretical frameworks with which to pose research questions about educational technologies for young children. This development will bring us closer by leaps and bounds to a common agenda: the effective and beneficial use of new technologies in education and a nuanced understanding of how new technologies can impact early educational endeavors. The fields are not so much in a race, after all, as they are engaging in intertwining efforts toward a similar goal. Indeed, it is to the benefit of the entire field of educational technology research, particularly for early education and young children, that different research is carried out at very different paces; these approaches complement and support each other, the one proceeding incrementally and the other reaching ahead, resulting in a stronger whole.

## REFERENCES

- Anderson, T., & Shattuck, J. (2012). Design-based research: A decade of progress in educational research? *Educational Researcher*, 41(1), 16–25.
- Barab, S. (2006). Design-based research. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 153–169). Cambridge, UK: Cambridge University Press.
- Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences*, 13(1), 1–14.
- Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K–12: What is involved and what is the role of the computer science education community? *ACM Inroads*, 2(1), 48–54.
- Bell, P. (2004). On the theoretical breadth of design-based research in education. *Educational Psychologist*, 39(4), 243–253.
- Bers, M. (2010). The TangibleK Robotics Program: Applied computational thinking for young children. *Early Childhood Research & Practice*, 12(2). Retrieved from <http://ecrp.uiuc.edu/v12n2/bers.html>
- Bers, M. U. (2012). *Designing digital experiences for positive youth development: From playpen to playground*. New York, NY: Oxford University Press.
- Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences*, 2(2), 141–178.
- Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, 32(1), 9–13.
- Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shei (Eds.), *New directions in educational technology*. New York, NY: Springer-Verlag.
- diSessa, A., & Cobb, P. (2004). Ontological innovation and the role of theory in design experiments. *Journal of the Learning Sciences*, 13(1), 77–103.
- Gravemeijer, K., & Cobb, P. (2006). Design research from a learning design perspective. In J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 17–51). New York, NY: Routledge.
- Gutnick, A. L., Robb, M., Takeuchi, L., & Kotler, J. (2011). *Always connected: The new digital media habits of young children*. New York, NY: The Joan Ganz Cooney Center at Sesame Workshop.
- Horn, M. S., Crouser, R. J., & Bers, M. U. (2012). Tangible interaction and learning: The case a hybrid approach. *Personal and Ubiquitous Computing*, 16(4), 379–389.
- Horn, M. S., Solovey, E. T., & Jacob, R. J. (2008). Tangible programming and informal science learning: Making TUIs work for museums. In *Proceedings of the Seventh International Conference on Interaction Design and Children* (pp. 194–201). New York, NY: ACM.
- Ito, M. (2009). *Engineering play*. Cambridge, MA: MIT.
- Kazakoff, E. R., & Bers, M. U. (2011, April). *The impact of computer programming on sequencing ability in early childhood*. Paper presented at American Educational Research Association Conference (AERA), New Orleans, LA.
- Levy, S. T., & Mioduser, D. (2008). Does it “want” or “was it programmed to...”? Kindergarten children's explanations of an autonomous robot's adaptive functioning. *International Journal of Technology and Design Education*, 18(4), 337–359.
- Mioduser, D., Levy, S., & Talis, V. (2009). Episodes to scripts to rules: Concrete-abstracts in kindergarten children's explanations of a robot's behaviors. *International Journal of Technology and Design Education*, 19(1), 15–36.
- Mioduser, D., & Levy, S. (2010). Making sense by building sense: Kindergarten children's construction and understanding of adaptive robot behaviors. *International Journal of Computers for Mathematical Learning*, 15(2), 99–127.
- NAEYC & Fred Rogers Center for Early Learning and Children's Media. (2012). *Technology and interactive media as tools in early childhood programs serving children from birth through age 8*. Washington, DC: NAEYC; Latrobe, PA: Fred Rogers Center for Early Learning at Saint Vincent College. Retrieved from [www.naeyc.org/files/naeyc/file/positions/PS\\_technology\\_WEB2.pdf](http://www.naeyc.org/files/naeyc/file/positions/PS_technology_WEB2.pdf)
- Papert, S. (1993). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Books.
- Papert, S. (1999). Logo: What is Logo? Who needs it? In: *Logo philosophy and implementation*. Retrieved from [www.microworlds.com/company/philosophy.pdf](http://www.microworlds.com/company/philosophy.pdf)
- Papert S., & Harel, I. (1991). Situating constructionism. In S. Papert & I. Harel (Eds.), *Constructionism* (pp. 1–11). Norwood, NJ: Ablex.
- Resnick, M., (2007). Sowing the seeds of a more creative society. *Learning and Leading with Technology*, 35(4), 18–22.
- Rainie, L., & Duggan, M. (2012). *E-book reading jumps; Print book reading declines*. Washington, D.C.: Pew Research Center's Internet & American Life Project

- Retrieved from: [http://libraries.pewinternet.org/files/legacy-pdf/PIP\\_Reading%20and%20ebooks\\_12.27.pdf](http://libraries.pewinternet.org/files/legacy-pdf/PIP_Reading%20and%20ebooks_12.27.pdf)
- Shavelson, R. J., & Towne, L. (2002). *Scientific research in education*. Washington, D.C.: National Academy Press. Retrieved from: [http://www.nap.edu/catalog.php?record\\_id=10236#toc](http://www.nap.edu/catalog.php?record_id=10236#toc)
- Sullivan, A., & Bers, M. U. (2012). Gender differences in kindergarteners' robotics and programming achievement. *International Journal of Technology and Design Education*. doi: 10.1007/s10798-012-9210-z
- van den Akker, J., Gravemeijer, K., McKenney, S., & Nieveen, N. (Eds.). (2006). *Educational design research*. New York, NY: Routledge.
- Wartella, E. A., & Jennings, N. (2000). Children and computers: New technology—old concerns. *Future Child*, 10(2), 31–43.
- Wyeth, P. (2008). How young children learn to program with sensor, action, and logic blocks. *Journal of the Learning Sciences*, 17(4), 517–550.

## CHAPTER 9

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# USING VIDEO MODELING IN CONDUCTING RESEARCH WITH YOUNG CHILDREN

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The use of video modeling as an intervention for children with disabilities has been established as an evidence-based practice (Wang & Spillane, 2009). The term *video modeling* is the general term to classify interventions in which students view a video clip of a task or skill being performed followed by an opportunity to perform the task or skill. Video modeling encompasses interventions that use other-as-model (e.g., peer or adult), interventions that use the self-as-model (video self-modeling), and interventions that use person-point-of-view (no modeling). Person point of modeling shows a task or skill being performed from the observer's vantage point which does not include a model although in some cases a person's hands may be included.

Videotapes are individualized for the student and may be created for a wide array of skills (e.g., social, communication, functional) and in a variety of settings (e.g., home, school, community). The vast majority of research that supports the use of video modeling incorporates single-subject design methodologies. Single-subject or single-case design research is