Preface

Educators are developing a variety of ways to utilize the powerful capabilities of the Internet to improve science teaching and learning for elementary, middle, and high school students. One of the best known and earliest of these efforts is National Geographic Kids Network—a curriculum that was initially developed by TERC and the National Geographic Society in the late 1980s with funding from the National Science Foundation. Since then, many other efforts have emerged that are similar enough that we refer to them collectively as network science curricula. Although each network science curriculum has its distinctive features, they all make use of online communities and shared sets of data to support students learning science. Whether the topic is acid rain (NGS Kids Network), environmental science (Global Lab), or butterfly migrations (Journey North), network science curricula have sought to enhance student learning through telecommunications.

Two research projects are responsible for the work reported here. Testbed for Telecollaboration (active from 1994–1998) and its predecessor, Alice/Collaborative Inquiry Testbed (active from 1992–1994), were funded by the National Science Foundation to support and research the implementation of network science curricula. As *testbeds*, these projects were designed to mesh with the efforts of partner organizations and develop common models and test conjectures about uses of technology in science education. Both Testbed projects were located at TERC, an educational research and development organization in Cambridge, Massachusetts, whose mission is the improvement of mathematics, science, and technology education.

The first goal of Testbed for Telecollaboration and its predecessor was to develop the technical infrastructure needed to serve multiple network science curricula and to research the use of this technology in classrooms. Testbed staff pioneered the web-based server technology that supports many of these curricula (Feldman, Johnson, Lieberman, Allen, & van der Hoeven, 1995) and passed it onto some of its partner projects for use in other web sites. The staff also designed and built a working prototype for the telecommunications and data analysis tool that was released as *NGS Works* in 1997.

The second goal, research, culminated in the writing of this volume. Our research efforts included these four activities:

- working actively to support partner groups creating network science curricula, especially by providing assistance in data use and data analysis;
- learning from the experiences of these partners' efforts to develop, test, and implement network science curricula;
- fostering communication among the staff of these partner groups; and
- disseminating the knowledge arising from these endeavors.

Dissemination, for us, became integral to the entire research effort. Indeed, our decision in the spring of 1997 to write a book refocused our research efforts. The *what* emerged in the following months as the six of us sifted collective experiences—foremost, our experiences working and observing in classrooms as well as what we had learned from solving problems with the staff of partner projects.

As the message took shape, the issue of audience became clearer. As a result, this book is directed specifically toward the type of individuals with whom we had been collaborating—namely, project organizers, curriculum developers, researchers, and teachers who together are the pioneers in this unfamiliar landscape of educational technology. As our work neared completion, we recognized that the perspectives and conclusions of our effort might also be useful to a wider audience: school-based educational leaders, policymakers, university-based faculty, and students enrolled in a variety of courses examining issues of educational technology. The final chapter responds to the questions this larger audience is asking—and asking with some understandable urgency.

Our work raises troubling questions about the current political reality in which educational technology has emerged for many as the panacea for the array of problems plaguing our schools. At the urging of politicians and parents, schools nationwide are rapidly installing multimedia computers, high speed networks, and other technology. Most often teachers have little support as they struggle to use the technology and incorporate it into their work with students.

Those who spend time in classrooms might find themselves asking these questions: Are these technologies well suited to the needs of the teachers and students on whose desks they are being placed? What benefits can the public expect from schools that adopt technology? How can we know whether these expectations are being met? The simple truth is this: We are only at the early stages in learning how to incorporate technology effectively in schools. The nationally recognized Panel on Educational Technology clearly stated this point in March 1997:

> It is natural to ask what is currently known and what remains to be learned [about the use of computers in schools].… A review of the relevant research literature, however, suggests that although a substantial amount of very interesting and potentially significant work has already been done, we are not yet able to answer this question… the Panel believes such research to be critically important.… (p. 87, 91)

Despite a decade or more of technology use in schools, serious empirical studies that claim evidence of change are just now appearing (e.g., Wenglinsky, 1998).

Meanwhile, a reaction to the uncritical use of technology has surfaced in the press in the last 2 years. The well-publicized cover story in a national magazine on the use of technology in the classroom (Oppenheimer, 1997) as well as a publication on the effect of technology use on young children (Healy, 1998) sought to puncture the public's uncritical belief that computers in classrooms will, by themselves, help schools improve student learning. Both Oppenheimer and Healy questioned the costs and benefits of technology. Although remaining optimistic about the potential of educational technology to transform and improve educational practice, we agree that many schools have adopted technology without understanding—and committing to—the curricular and pedagogical changes that technology makes possible, and to the institutional changes that technology necessitates.

In our analysis, we have tried to debunk the idea that technology is a panacea. To see what a mixed blessing technology can be, one only has to look in many of the classrooms we have visited where teachers are struggling to master the technology while learning to teach new materials using unfamiliar pedagogies. However, we have also worked in classrooms where telecommunications has opened up avenues of inquiry-based teaching and technology is infused into many aspects of student learning. For the teachers and the students in these classrooms, teaching and learning without the enhancements and support of technology is hard to imagine.

This debate about the role, effectiveness, and costs of technology will be resolved neither quickly nor easily. Multiple questions about educational goals and alternative uses of limited resources hinder our ability to structure the debate. Nevertheless, our hope is that the research and theoretical perspectives on which we base our work will be of use to those educators who are pressing ahead (despite the debate) to develop sensible uses of technology. We remain optimistic that, given sufficient time for development, refinement, and implementation, technology will have a powerful impact on what and how students learn.

RESEARCH BASIS

Over the last 4 years, the Testbed for Telecollaboration worked most closely with four network science curricula, providing services and direct support to Classroom BirdWatch, EnergyNet, Global Lab, and NGS Kids Network. (See Appendix A for brief descriptions of these network science curricula.) Other network science projects with which we cooperated in myriad ways include EnviroNet, EstuaryNet, Global Rivers Environmental Education Network (GREEN), Global Thinking Project, International Education and Resource Network (I*EARN), Journey North, and Kids as Global Scientists.

These network science curricula not only encompass great diversity but also possess the common elements of shared data and online communities. Several of these curricula, such as

Global Lab, were inspired by the early model of network science and maintain a strong resemblance to it. Others such as Journey North have pioneered substantially different approaches. In this volume, we explore some of the differences and the implications they have for the future of network science.

Although our work has been anchored in the experience of the Testbed researchers who worked closely with staff, teachers, and students of various network science curricula, it has also been informed by two additional sources of data. At the Network Science Conference, a diverse group of 33 curriculum developers, project organizers, teachers, researchers, and funders of network science curricula gathered at TERC to share their experiences and discuss the state of the art and future directions of network science. (See Appendix B for a list of participants at the Network Science Conference.) These discussions were provocative and far-reaching and inspired many of the ideas expressed herein, especially the lessons described in chapter 3. We are grateful for the contributions of the participants—for their thoughtful responses to an initial set of questions, for sharing their experiences at the conference sessions, which we taped, and for responding to the conference summary that we distributed afterward. In the months following the conference, we found ourselves returning frequently to these materials.

The Goodman Research Group Evaluation Report (1998) provided us with the second source of additional data. TERC contracted with Goodman Research Group for an external evaluation of Testbed for Telecollaboration during the project's third year (1996–1997). For this evaluation, GRG examined five different network science curricula. In conducting this comparative analysis, GRG examined three curricular projects that worked closely with the Testbed (Classroom BirdWatch, Global Lab, and EnergyNet) and two other network science curricular projects that were independent in their operation (Journey North and EnviroNet). The evaluators conducted interviews and surveys of teachers and project staff across all five curricula and supplemented these with data collected by each project whenever available. We found the data collected by the evaluators to be useful in our documentation of the conclusions of our work. (See Appendix C for the executive summary of the GRG Evaluation Report.)

Research, by its nature, is not neutral, and we do not intend that ours should be. Rather, we aim to be aware—and make our readers aware—of the beliefs that underlie the questions we ask and the methodologies we use. Foremost among our beliefs is the value we place on inquiry-based teaching and learning—a perspective enthusiastically supported in the national standards in science and mathematics. Our research is not designed to evaluate the value of inquiry-based approaches to teaching and learning. Rather, it examines the role that technology can play in fostering these approaches.

ORGANIZATION

Part I: State of the Art

The first three chapters describe the history and current practice of network science. Chapter 1, "Founding Vision of Network Science: Assessment," reconstructs the vision that emerged a decade ago among the group at TERC who imagined new curricula based on telecommunications capabilities that would foster inquiry-based science education. It is the nature of visions to motivate new efforts, and in this way the bold and inspiring network science vision was enormously successful. As often happens, the limitations of any founding vision become evident over time. We identify four aspects of the founding vision that have proved problematic.

Chapter 2, "Evolving Visions: Case Studies," presents the evolution and current state of three network science curricula: NGS Kids Network, Global Lab, and Journey North. The stories of these curricula illustrate the different ways that the network science vision has developed. We use these stories, which include the challenges faced by curriculum developers and project staff, to shed light on the founding vision identified in chapter 1 and point to promising new directions.

In chapter 3, "Lessons Learned," we look across the experiences of multiple network science curricula to identify what we and others have learned about using Internet resources to strengthen science teaching and learning. The seven lessons include priorities for curriculum development (e.g., "Look locally before globally") as well as advice on building infrastructure (e.g., "Design robust systems"). From these lessons, we identify and develop one of our key recommendations: The Internet should be used to broaden the scope of investigations that have begun with students studying phenomena locally.

Part II: Looking Deeply

Despite what we have learned from the experiences of network science curricula, we see clearly that discourse and data, both critical to inquiry-based learning and teaching, need particular attention. The next two chapters extend our inquiry into network science by examining discourse and data in depth, using both empirical data and theoretical perspectives.

Chapter 4, "Promoting Reflective Discourse," examines how best to support class discussions. One goal of the founders of network science was that students, like collaborating scientists, would use the Internet to share data as well as ideas and would engage in serious discussions with one another. The evidence to date is not encouraging. Our research shows that online discussions in network science curricula are typically social in nature and not related to the substance of the science being studied. Based on our analysis of a transcript of a classroom discussion, we conclude that substantive online discussions are not likely to occur without a high level of support from the teacher and a classroom culture that values such discussions. We have difficulty imagining how to provide this kind of support online. We argue that it is less important where these discussions occur than that they occur somewhere. We conclude the chapter by discussing the type of curriculum-based support that teachers of network science need, but have not been getting, to promote reflective discussions in their classrooms.

Chapter 5, "Bringing Students to the Data," applies the insights of the mathematics education literature to the issues of data use in network science curricula. We begin with the observation that, despite our determined attempts, we have not been able to find classrooms in which students analyze in any depth the data made available to them. There are many reasons for this. Paramount among these is that students generally do not have in mind questions they want answered as they dutifully collect and upload data. We outline a set of principles for selecting tasks, data, and analysis tools appropriate for students. These principles are motivated and illustrated in two case studies: one of an expert analyst and the other of fourth-grade students being assisted by their teacher.

Part III: Looking Forward

In the final chapter, "The Internet and Classroom Learning," we step back from the issues of network science to take a broader view. We focus on this question: How should the Internet be used—and *not* used—to support student learning?

We respond to this question in two complementary ways. First, we describe broad themes that have emerged from our work about the role of the Internet in classroom learning. Second, we look at how these themes are played out in a classroom. We present a vignette of a teacher we call Debra, who is actually a composite of teachers with whom we have worked. When we first see her, she is a good teacher who uses technology in marginal ways. We look again 3 years later after she has integrated online resources with her day-to-day teaching and observe how her teaching practices have changed as a consequence.

We conclude this work with a reminder that technology will not replace teachers. Rather, the power of these new technologies to give students both an overwhelming access to resources—experts, peers, teachers, texts, images, and data—and the opportunity to pursue questions of their own design increase the need for highly skilled teachers and forward-looking administrators.

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Research associates Brian Conroy and Charlie Hutchison and research assistant Nancy London played important roles in the researching and writing of this book. Brian and Charlie currently work on a variety of research and development projects; both are former teachers of elementary and middle school students. Nancy has finished her graduate studies and is pursuing a career in public health.