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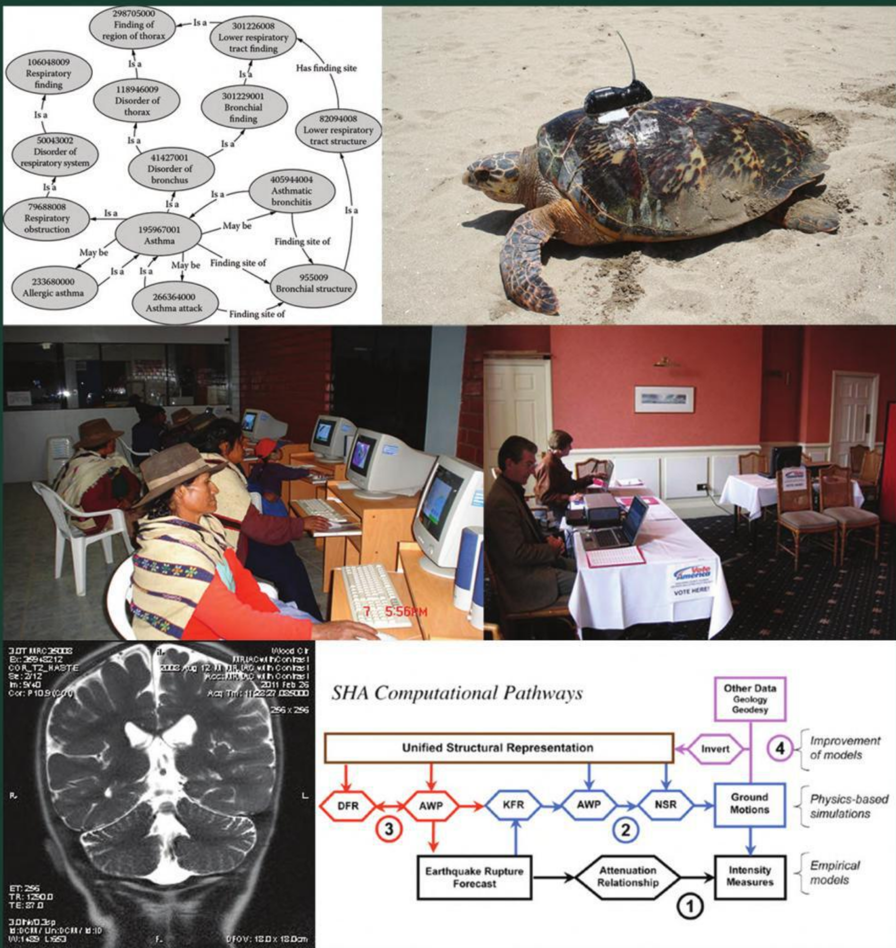
COMPUTERS AND SOCIETY

COMPUTING FOR GOOD



LISA C. KACZMARCZYK

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A CHAPMAN & HALL BOOK

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Introduction

This book came into existence because of the intersection of personal passions and practical observations. The passions are both mine and those of the people profiled in these chapters. The practical observations, made over many years teaching both traditional and interdisciplinary computer science courses, I take responsibility for.

Courses designated as "computers and society" courses have often been designed for the freshman level or for a general audience. These courses serve a purpose. However, by placing these courses at that level and toward that broad of an audience, some people have questioned whether or not societal topics constitute "real computer science." After all, if there is no "technical meat" to it, is it computer science? I don't want to get drawn into a definitional debate; many others are working on that one. My point is this: The tendency in some camps to dismiss lower division coursework in computers and society as "not real computer science" leads to a self-reinforcing pattern whereby students and faculty alike give little attention to a critical aspect of computer science education. Every professional decision a computer scientist makes has a societal context and societal influence; for ethical reasons if nothing else, this understanding must be integrated into computer science education. Supporting evidence is needed and supportive materials are needed. Therefore a book on computing and society targeted at a higher level audience is needed—a book with "technical meat" in it. A book that will hopefully convince the fence sitters, that yes, computer and society material belongs in a computer science curriculum and it should be taught by computing faculty.

From here forward I will use the word "computing" frequently. This choice is intentional and strategic. I want to make it clear that I believe the above argument applies not only to computer science, but information systems, computer engineering, software engineering, and other flavors of "computing" degree programs. In addition, I want to acknowledge that outside the United States the term "computing" is often preferred over the term "computer science."

My primary goal in writing this book is to address two issues. First, there is an increasing emphasis in computing curricular guidelines for inclusion of more "computers and society" material. Incorporation and presentation of this material vary widely depending upon the institution and program, but discussion is showing up more and more at conferences such as SIGCSE (the primary computer science education conference) and its sister conferences around the globe. Accrediting agencies such as ABET have paid increased attention to societal issues in recent years. Departments are responding to industry calls for students with well-rounded educations and an understanding of how their technical decisions affect the world around them.

However, there has been a tendency for "computers and society" coursework to be translated as meaning "ethics." There is nothing wrong with a study of ethical decision making in computing; in fact, ethical considerations are important and appear throughout this book. But placing a primary focus on ethics generally leads to discussions of how things go wrong. We are not doing our students (or the general public) any favors by sending the message that societal issues in computing are all about examples of the negative effects and damage caused by computer software and systems. Formal exposure to societal issues in the curriculum should not start with (and often end with) negative consequences and how they can be avoided. We need to incorporate in our curricula a clear message that computers and computing systems can be powerful engines for creating social benefits.

Again unfortunately, there is a dearth of books that provide concrete examples highlighting the positive work computing professionals are doing in the world; people students can emulate, use as role models and inspiration. This book provides case studies of real people, real organizations, computing professionals making a living pursuing dreams of making the world a better place.

Each chapter is a profile of a group or organization doing something computing centric that is clearly good for society or the environment. The profiles include corporations, nonprofit organizations, and entrepreneurs. The coverage of computing topics spans the curriculum, from social networking to high performance computing. The application domain areas include cultural adaptation in a developing country, cutting edge medicine and healthcare, educational innovation, endangered species work, earth sciences, and voting. The diversity of people and activities presented in these profiles will give students a broader vision of what they can do with their computing degree.

The second goal of this book is to target upper division undergraduate computing students. Typically, societal issues are dealt with in one of two ways (if they are directly addressed at all) in the computing curriculum: through a general education or first year course with little prerequisite technical knowledge, or as part of a final year capstone project. In the first case, the course may be taught by faculty from another department, lacks technical "meat" and reinforces the message that societal issues in computing are not a central part of "real computer science." In the second case, students may receive an in-depth client project experience but do not learn about the breadth of opportunities available to them after graduation. This book addresses these issues by providing both breadth and depth of material, clearly placing it in the domain of the computing curriculum. By providing examples of professional opportunities where students can use their computing education to make the world a better place, this book demonstrates that no matter what area of computing and society interests them, there is a professional path for them.

Each chapter assumes technical knowledge in one or more areas of computing. Depending upon the focus of a computing program and the background of the students, some parts of the book may appear relatively easy to grasp and other parts quite challenging. Reviewers of early versions of this manuscript confirmed this; their comments concerning the level of difficulty and appropriate placement of a course using this material directly reflected their own students and background. However, as intended when I set out to write this book, there was agreement that this is not a book for students who lack a computing background. The material in these profiles balances the expectation that students have had exposure to concepts typically covered in the first few years of a computing curriculum with the realization that programs vary, curricular requirements vary, and therefore some technical explanations are needed.

For students with less technical preparation, sufficient information is given such that the upper division student should be able to follow the conversation well. For the student who has greater technical preparation or who is interested in additional depth, sidebars are liberally spread throughout each chapter. This pedagogical technique allows the student who wants additional material to have it, and the student who does not want or need that material to skip over it. Even if the reader decides to skip every single sidebar the primary technical and societal objectives of each chapter will still be met.

Layout of the book

Each chapter begins with a short introduction for the student. This introduction provides an overview of the profile topic (technical and societal), the main take home points, and the computing skills needed for a project such as the one they are about to read about. Next, the introduction provides a similar short discussion of the relevant non-technical skills and interests students would bring to professional work in this area. The intent of this introductory section is to orient the student by providing her or him with a profile context and an answer to this question: "What can I do with the information I am about to read?"

The end of each chapter has an exercises and activities section with questions designed to encourage the student to engage actively and critically with the material in the chapter. None of the questions involve rote memorization or regurgitation of material. They vary in difficulty, but share a common approach of asking the students to stretch their thinking, apply the material to themselves or their surroundings, and to think critically about the material from the perspective of a future computing professional. The exercises and activities section includes not only relatively straightforward questions, but a variety of projects suitable for students with greater or lesser preparation. Pedagogical projects include individual projects, team projects, short projects and projects that could easily become term projects. The instructor has choices and can select the question(s) that fit best with how they decide to integrate the chapter material into their courses. The supplemental sidebars are likewise varied; some contain general interest material, some are moderately technical, some are highly technical; a few are tangential but thought provoking.

Chapter 1 showcases a successful poverty alleviation project that took place in the remote Peruvian Andes. In some ways this is a "classic" case study, the type most people assume I am talking about when I tell them I investigate socially beneficial uses of computing. For this reason I have placed it first in the book. However, there is an important twist to this story, which is the other reason I placed it first. To ensure a successful outcome the computer scientists had to use highly unusual methods of software engineering—unusual to them that is. The most critical factor in the success of this project was not technical. Success relied on their adapting to the culture and customs of the local population however alien this felt.

Chapter 2 is the first of two chapters about computing and healthcare. Many science-oriented students consider a career in medicine; this appears particularly true for women and other underrepresented groups. As luck would have it, the intersection of computing and medicine is an exploding field with endless exciting professional opportunities for computing students. This chapter delves into digital image management and storage, and how a visionary hospital administrator partnered with a high tech firm to overhaul a system that no longer served hospital needs. There is cutting-edge material in this profile about data access in very large scale complex system projects, and challenges in electronic standards development. This project shows computing teamwork at its best, ensuring that an internationally renowned hospital completed a year-long system overhaul without compromising patient care.

Chapter 3 is by far the most controversial chapter. This came as a surprise, but caused me to appreciate the project and the people who saw it through even more. The topic is Internet voting. The technical issues revolve around security of highly sensitive data (how people vote in an election). It will become clear to the reader that difficult choices have to be made when designing network security projects. Philosophical differences drive the debate on Internet voting among computer scientists. This project demonstrates that Internet voting can be implemented well and enable American citizens to vote who previously had difficulty voting. Computing students reading this chapter will be challenged to form their own sound technical opinions about how and when to use the Internet for routing highly sensitive data.

Chapter 4 tackles a so-called "soft topic"—the skillful use of social media and social networking. In this profile we meet a nonprofit organization that leverages social media to advance the cause of protecting endangered sea turtles. This chapter demonstrates that it takes solid computing skills to use the entire range of social media effectively, in areas such as user interface design and creating data-driven descriptive models. One of the curricular attractions to me about this profile is that it debunks any perception that working as a user of social networking cannot be "real computer science."

Chapter 5 is the second profile on computing and medicine. This project is quite different from the profile about digital imaging. A team of physicians works closely with a children's healthcare company to develop a database for collecting, tracking and analyzing data on rare medical conditions in newborns. Their mutual goal is to mine the aggregate information for best practice recommendations. This chapter, more than any other, discusses the daily challenges of running a highly complex software project on a very tight deadline. The computer scientists on this interdisciplinary team were willing to (in fact asked me specifically if they could) share information about "lessons learned." As an added bonus to students interested in the medical field, this chapter highlights just how embedded computing concepts and approaches are becoming in healthcare data modeling and standardization efforts.

Chapter 6 digs into the world of earthquake modeling and simulation. High performance computers are critical to creating the detailed graphic representations of data used to study earthquake behavior and to make the best possible predictions about when and where earthquakes will occur. This is the only chapter that profiles an organization where an advanced degree (MS or PhD) is probably required to work in the field. Students considering post graduate studies will thus be given something new to think about. Computing students who are interested in the earth sciences or another natural science will learn about a way to pursue their interests. This profile provides an exemplar of how a computing student can perform theoretical and applied research in an interdisciplinary science for the benefit of society.

Chapter 7, the final chapter, addresses the question: What if I want to strike out on my own? What if I have an idea for my own computing business? How do I go about it? The profile in this chapter is of a computer scientist who did just that. After a personal event changed her life, she decided to create a software and services company to infuse educational software running on mobile devices into the school system. This profile has a decidedly different flavor than the other chapters. It dives into the business issues that must be addressed when creating a start-up company Thus, this chapter speaks to several audiences. It speaks to students interested in educational software, mobile devices, and students with disabilities. The chapter also speaks to students who have a strong interest in business processes in technology companies. It speaks to students who want to gain a sense of additional areas, such as technical marketing, where they can apply their computing skills professionally.

How to use this book

In the summer of 2010, at the ITiCSE conference, a working group produced an excellent report entitled: "Enhancing the Social Issues Components in Our Computing Curriculum: Computing for the Social Good." This report (fully referenced at the end of this section) does a magnificent job of laying out, in aggregate, common curricular approaches to infusing social issues into the curriculum of computing programs. I owe a debt of thanks to the work of this group in the section that follows and refer you to this document as an excellent reference work.

There are five ACM computing curricula documents for undergraduate level programs: computer science, information technology, information systems, software engineering and computer engineering. Societal topics are identified in each of these curricular guidelines as both core and elective material. The curricular guidelines can be downloaded from the ACM website (http://www.acm.org/education/curricula-recommendations). As implied in the prior part of this introductory section, there is no agreed upon approach to including societal material: where, how, when, how much, etc. Each instructor must make his or her own decision, taking into account the minimum factors:

Type of Program:
(CS, IT, IS, SE, CE)
Number of Weeks in Term:
(I.e., approximately 8 vs. 16 weeks, or summer school ranging anywhere from 3–8 weeks.)
Distribution and Number of Courses on Computing and Society:
(One stand-alone course, one integrated subject matter course, a capstone project course, several integrated subject matter courses, topic modules plugged into a variety of courses, societal material fully distributed and integrated across the curriculum.)

Preparation of Students:
(This dimension is a composite of demographics, type of program and requirements in that program and how the societal issues are distributed through the curriculum.)
Class Size:
(Definitions of small, medium, and large are completely relative. However, if a large lecture hall with hundreds of students is required, a very different pedagogical approach will be more effective rather than if a small room of under 20 students is used.)
Faculty Interested and Prepared to Teach Societal Material:
(Are you the only one? Are others interested in team teaching? Alternating teaching the course or courses?)
Degree to which ACM or IEEE Guidelines are Followed and if ABET Accreditation is a Consideration.

There are many ways to use this book. The suggestion is to analyze your interests and constraints in each of the above categories. Then decide whether a term project from one of the exercises and activities sections is appropriate, a series of smaller projects from one or more chapters, or a reliance on non-project pedagogical questions. The chapters work well if read in order, as they have been arranged to create a progressive flow; however, it is entirely possible to use the chapters in any order as there is no direct dependence between any chapter and another.

A standard approach is to use this book as the primary text in a stand-alone course in which the students analyze a chapter every week or every other week, depending upon their level of preparation and technical sophistication. A term project that focuses on an expanded analysis of one of the chapters, and is taken from the exercises and activities section, could start early in the course and continue through the term as other chapters are analyzed for common themes and aids to completing the project.

For students with less technical background or interests, more weeks can be spent on selected chapters. For example, Chapters 1, 4, and 7 have the lightest technical expectations. Chapters 5 and 6 have the most demanding technical expectations and Chapters 2 and 3 are somewhere in the middle.

Another option for a stand-alone course using this book is to select specific chapters with a common technical or non-technical theme (the environment, healthcare, security, high performance computing) and use the profiles to closely examine that aspect of computing.

This book can be used as a supplemental text using a similar approach to selecting how many chapters to use, which ones to use and what assignments to use. The primary difference in this scenario is that the choice of profiles would either complement or contrast with the other materials used in the course. The selected profiles could cover topics (emerging trends in data standardization in healthcare) not covered elsewhere or could add depth to a topic lightly covered elsewhere (scientific modeling of natural phenomena without a good example).

Finally, I have created a website to go along with this book. The website contains a variety of materials and resources for instructors and students. You can access the website at: www.computers-and-society.com.

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Goldweber, M., Little, J. C., Cross, G., Davoli, R., Riedsel, C., von Konsky, B. R., and Walker, H. (2011). Enhancing the social issues components in our computing curriculum: Computing for the social good. (March) *ACM Inroads* 2(1):64–73.

Acknowledgments

To risk using an unoriginal but quite accurate phrase, this book has been a labor of love and perhaps the most exciting project I have ever worked on. I have been given the opportunity to meet dozens of people who took time out of their packed schedules to talk with me, patiently answer my questions over email, phone, Skype and occasionally in person. Each one of these people shared their professional passion for using computer science for the benefit of society and gave me an understanding of their field I could never have gained from reading and research alone. At the end of each chapter I have acknowledged the individuals who worked with me to develop an accurate profile of their projects. I wish there was some way to convey better how honored I feel to have met each of them and learned about their work.

I may have written the words, but a project such as this never could have happened without people "behind the scenes." In almost every case, it was a professional colleague I know or someone I heard at a professional meeting and then tracked down, who connected me to the organizations you read about here. These same colleagues believed in me and this project enough to make the all important initial introduction to the right person. I have listed these people in the end of chapter acknowledgments as well. The people who reviewed this book provided very useful advice and deserve a big thank you. If I have inadvertently left anyone out, I apologize profusely.

I want to acknowledge two of these behind-the-scenes people in particular. Mary Last, a longtime friend who has published more books than I can count, gave me expert advice early on about how the world of publishing works from the perspective of the prospective author. Peter DePasquale is another longtime friend who has published many textbooks and frequently shared his experiences and perspective. Pete's advice and friendship have been invaluable. In addition, Pete always had his ear to the ground and told me about anything he heard about or thought of that might be good profile material. Four of his ideas eventually became chapter profiles! You can take a break for a while, Pete!

As most of these chapters demonstrate, it takes more than a good idea to bring a project to fruition. The same applies here. I have been passionate about societal issues in computing for years and always wanted to write a book. My longtime professional colleague and friend John Impagliazzo (sometimes referred to by friends in terms denoting royalty) has been a consistent supporter in this and other endeavors. Quite a few years ago, perhaps having grown tired of hearing my enthusiastic burbling about wanting to write more than academic articles, John offered me the opportunity to author a column for *ACM Inroads* magazine, of which he is editor in chief. Sometime after that, it was John, who having heard me jubilantly share my desire to write a book, introduced me to Randi Cohen, acquisitions editor at Taylor & Francis. John is probably wondering what I'll start talking about wanting to do next.

Randi has been a terrific person to work with as an editor. As I progressed from a somewhat unsuspecting first-time book author to a less unsuspecting first-time book author, Randi was always helpful and supportive. As much writing as I have done in other venues, taking on a book is a whole new adventure. Not for the timid. Whenever I had questions or sometimes when I didn't, Randi gave me straight information and practical advice. If it wasn't what I wanted to hear, I still felt respected. Over time I have come to realize that her friendly, personable manner is not only who she is, but sits on top of a great deal of experience and knowledge. The more I learned, sometimes the hard way, about how to work with the challenges of writing a book like this, the more I came to realize what a good job Randi does. She keeps very much on task yet is well attuned to whom she is speaking. In the middle of writing this book I experienced some personal upheavals that without doubt delayed my progress. I am grateful beyond words for Randi's understanding and tolerance during an incredibly difficult time for me. I look forward to, at the very least, enjoying more of our annual vegetarian lunches together.

I have to also acknowledge some other people who were behind me all the way. My parents, both published authors, must have given me the genes as well as the insatiable curiosity that drives my quest to always ask more questions and investigate things just one step further. I am sad my father passed away before this book was finished; I know he wanted to see it. I am looking forward to finally (finally) depositing a copy of this on my mother's doorstep. Mom will be happy, too, because it will mean I am more available to talk to her. Other people who have been personal cheerleaders and invaluable supporters are David Alexander, Bob Solomon, Geri Portnoy, Ellen Prediger and Kim Dean. Thanks so much all of you.

Author

Lisa C. Kaczmarczyk, PhD, has over 18 years of faculty experience with a research specialty in computer science education applied learning theory. She earned an interdisciplinary doctorate from the University of Texas at Austin. Her committee consisted of faculty from computer science, science education, mathematics education, and psychology. Her dissertation utilized artificial neural networks to model human learning, followed by human subject studies that investigated the predictions of her computational model. Dr. Kaczmarczyk also earned a master's in computer science from the University of Oregon, a master's in information systems from Northeastern University and a dual BA in Spanish and drama from Tufts University. She completed extensive graduate level coursework in intercultural communication studies and systems science.

Dr. Kaczmarczyk has taught computer science across the curricula at research universities, private undergraduate institutions, and at a community college. In addition to traditional computing coursework, she developed classes in cognitive science, technology and sustainability, and rhetorical–literary analysis of seminal papers in computer science. Dr. Kaczmarczyk has published numerous peer-reviewed articles and served multiple times as a committee member for the SIGCSE, ICER and Grace Hopper Celebration of Women in Computing conferences. She has been awarded funding by the National Science Foundation and currently consults as an external evaluator on NSF-funded research projects. Dr. Kaczmarczyk is a member of the ACM Education Council, is an associate editor of *ACM Inroads* magazine, and has written a regular column for *Inroads* for several years. Dr. Kaczmarczyk maintains a blog about her professional activities and interests: http://computing4society.blogspot.com/.

chapter one

Poverty alleviation in the remote Peruvian Andes

1.0 Introduction

For hundreds of years farmers, ranchers and others living in a very remote part of the Peruvian Andes had maintained a balance with nature, existing in a very harsh environment. They had evolved a culture and ideology adapted to ensure their survival. When the industrialized world intruded upon their lives, the balance was disrupted and they fell into deep poverty. An international collaboration of governmental organizations, private companies and computer scientists initiated a project to alleviate their poverty yet permit them to retain their core values.

The people living in the villages that agreed to take part in this unusual project held a leadership role. The project was successful primarily because the outside team respected the villagers' non-western lifestyle and culture. The computer scientists, though well versed in traditional software engineering practices, recognized the need to employ non-traditional methods at every stage of the project. They succeeded in applying the most important tenets of software engineering by adapting them to the culture of the people in the villages. In the end, the computer scientists believe they learned as much as the Andean villagers. Lives were permanently changed for everyone involved in this project.

Technically, this chapter has a strong focus on the front end of software engineering, that is, requirements gathering and specification development, and on methods of installing a computing system that would live beyond the presence of the visiting computer scientists. The chapter follows the lead of the people interviewed who continually focused on how software engineers must be willing to adapt to local custom even when it means abandoning methods accepted in the developed world. This is a profile with adventure and surprises.

Computer scientists and villagers alike agree there is far more to preparing for a culturally sensitive computing project than acquiring technical skills. Language skills are helpful but not required. What is required: Cultural sensitivity, keeping an open mind, being willing at times to go to extraordinary lengths to think creatively, to cheerfully change direction when things don't go as planned, and be willing to listen without a personal agenda.

If you are interested in other cultures, if you want to travel as part of your work and immerse yourself in other people's lives, if you consider physical and emotional challenges as learning experiences, then working on what are commonly called "development projects" may be the path for you as a computer scientist. There are endless opportunities to work with different cultures, both within your own country and outside it, using computer science to help people improve their own lives.

Vignette

At 12,000 feet (3,660 meters) in elevation, and miles by foot or alpaca from the nearest "tourist destination," the town of Daniel Hernandez barely exists to the outside world. Offering no trendy upscale hotels, eco-resorts, or a youth hostel, the isolated villagers are primarily farmers—very poor farmers. Small children typically walk 30 minutes or more each way to and from grammar school and homework is done after chores; assuming there is electricity to see by.

Nonetheless, for several hundred years, until the middle of the twentieth century, the farmers and their families co-existed in delicate balance with a fragile ecosystem and a hostile climate. The Andeans evolved a sustainable co-existence with their environment whether they lived in the small towns or in isolated ranches on the sides of the mountains. The native language is Quechua (pronounced Ketch' Wa), spoken by 85% of the population; 15% also speak Spanish. Most of the population is illiterate but until recently there has been no need to read and write; traditions are strong, and orally transmitted. People depend heavily upon one another in this harsh landscape and walk hours from town to town when needed, forming tight knit, interdependent communities. For most people, travel down the mountains is still an uncommon event. Unfortunately, in the last decades of the twentieth century, with the arrival of multinational corporations and unscrupulous traders, the isolated towns and farmers were confronted with challenges to their culture and their ability to survive. They were thrown into a downward spiral of increasing poverty. These problems arose primarily because the villagers lacked the knowledge of the outside world with which to protect themselves from economic and environmental exploitation.

1.1 Systemic poverty and health problems in the villages

Peru ranges from sea level to over 15,000 feet (4,572 meters) high in the Andes. Many people live high in the mountains, far apart from one another, little known to the outside world. One of the 24 Peruvian regions is called Huancavelica, and is located in the central southern region of the Andes. Here you will find the town of Daniel Hernandez. One hundred and eleven farming communities, with an approximate population of 108,000 people, are spread thinly across almost impassable peaks, valleys, breath taking cliff drop-offs, and steep slopes. Impassable, that is, to modern western society. Roads? Sometimes. Pavement? Never. Ruts and bumps big enough to knock out every ball joint and loose screw—and guaranteed to slam your head into the roof if you aren't both secured to the seat and short of stature. Little grows or lives here; the primary crops are potato, maize and barley, depending upon the altitude. Alpaca are the only farm animal that can live at these altitudes and therefore are the primary source of many products, from food, to clothing, to transport, and material for sale in the cities far below (Figure 1.1).

Globalization has brought serious problems to the people of the Andes. For example, there are rich minerals, including gold, in the mountains. The byproducts of corporate gold mining include toxic chemicals that end up in the streams and air pollution from large smokestacks. Drinking water can become polluted without the villagers' knowledge. Soft drink companies place billboard advertisements for soda and snack food along well traveled routes and in the small towns. Soft drinks are not only expensive for a people that live primarily on a barter economy, but contribute to malnutrition and other health problems, including previously non-existent dental problems. Finally, unscrupulous traders, who appear unannounced, have taken advantage of the people's lack of knowledge of ever changing market demand, and often have paid minimally for products they then re-sell for much higher prices in the city. These developments have disrupted the delicate balance of life for the Andean dwellers.

Figure 1.1 Road through the Andes to the villages. (Copyright, 1st July, 2011, Alison Clear and Logan Muller.)

Severe poverty is the overarching result; their remote location makes it very difficult for traditional government agencies to help them (Figure 1.2). The townspeople want to maintain their lifestyle and cultural heritage, but they also want to obtain the knowledge to effectively co-exist in their twenty-first century reality. How can this be accomplished?

1.2 *A software engineering project as a response to poverty*

For the budding computer scientist, this dilemma has all the hallmarks of a software engineering project just waiting to happen. What can computers and computing professionals uniquely accomplish in this situation? They can provide communication to the outside world and the knowledge available there through using the Internet. Beyond that general overarching goal, it was not initially clear to a range of interested government and nonprofit organizations what mix of hardware and software would prove most effective nor how the computing systems would be set up and maintained. Established principles of software engineering would have to be adapted to the local environment and culture. Eleven towns became part

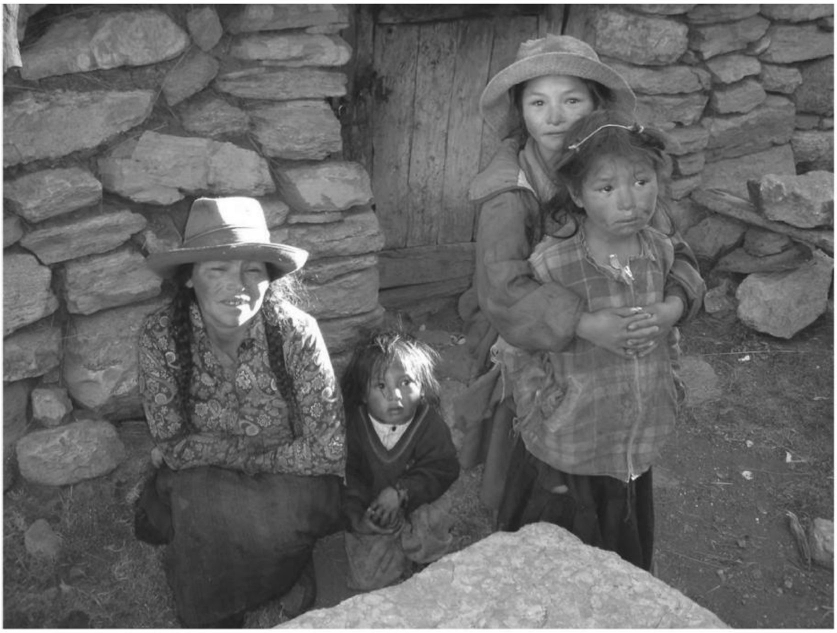

Figure 1.2 A mother and three of her children pose outside their dwelling. (Copyright, 1st July, 2011, Alison Clear and Logan Muller.)

of a pilot project developed through the cooperation of two countries and dozens of passionate, dedicated people.

Software engineering guidelines, whether industrial or contained in a textbook, always agree on one fundamental point: long before you touch the keyboard or begin to layout a technical design, you must truly understand your users' requirements. Otherwise, your project is bound to fail. Thus, the all-important task of Requirements Gathering and Specification Development is needed. What some textbooks do not tell you is there are many places in the world where the North American-based model of formal written contracts, lawyers, and other official documents don't apply. However, the basic principles of gathering accurate requirements to use in developing functional technical solutions **do** apply, and the first challenge becomes how to accomplish the data gathering.

1.3 The many challenges of requirements gathering in the Andes

A representative of the Peruvian Government who had contacts with computer scientist Logan Muller from Unitec Institute of Technology in Auckland, New Zealand, and who knew about Logan's prior experience with socially beneficial computing projects, approached the New Zealand Agency for International Development (NZAID) and asked if the two governments could collaborate on a poverty reduction project in the Andes villages we have been discussing. The organizations reached a basic agreement to collaborate. The Peruvian government's Ministry of External Relations chose the 11 most poor and remote towns for participation in the project. A truly creative approach was needed to help this extremely remote segment of the population. Logan Muller and Alison Young, another computer scientist from Unitec, wrote a formal proposal for funding from NZAID; the funding was awarded in the spring of 2003.

A fundamental requirement for accurate Requirements Gathering under **any** conditions is that all parties trust one another and communicate openly. In this case, although the Peruvian villagers were willing to work very hard to improve their situation, they had many reasons to distrust anyone from outside their region.

Number 1 Problem to Overcome: MISTRUST.

Over the past several decades, the villagers had to deal repeatedly with corrupt government officials and terrorist groups that decimated villages, drove off populations, and murdered people for seemingly meaningless reasons. Multi-national mining and manufacturing corporations moved in to access the area's natural resources. As environmental degradation began and public health was clearly compromised promises of help from the corporations were not honored. Local government representatives were either powerless to intervene, or at times were corrupt and colluded with more powerful interest groups at the expense of the local population. The villagers were well aware they were being taken advantage of economically but had no resources to take meaningful action (Figure 1.3). They needed the ability to communicate with the outside world in order to obtain knowledge they could use for their future survival.

Cultural issues that had contributed to community survival for hundreds of years also made them vulnerable to exploitation. The villagers have a saying: "*Un Solo Pensamiento, Una Sola Fuerza, y Un Solo Sentimiento*" which loosely translates to: "*One Thought, One Power, One Feeling.*" They also have clearly stated ethics: "*Ama sua* (do not rob)," "*Ama quella* (do not be lazy)," "*Ama llulla* (do not lie)." These simple words formally acknowledge the interdependence that had ensured their survival for centuries in a hostile climate. Unfortunately, these beliefs also left the villagers open to exploitation by people who did not follow the same professional or personal ethics. For example, when meeting strangers the villagers would assume positive intentions and a desire for open collaborative communication; they would not expect to be taken advantage of. People from outside the village might call them "naïve"; however that word implies one culture is more advanced or "better" than another—something the Andean villagers would strongly disagree with.

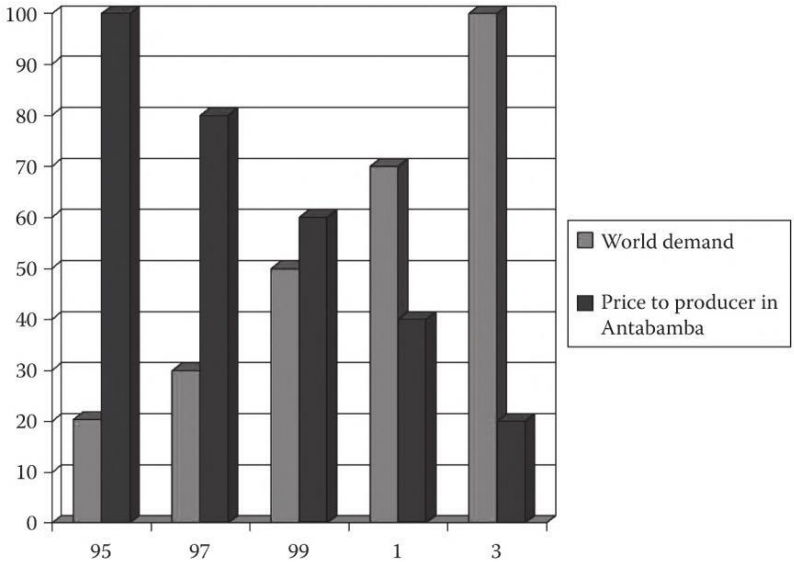

Figure 1.3 Payments to Antabamba villagers relative to world demand, 1995 to 2003. (Copyright, 1st July, 2011, Alison Clear and Logan Muller.)

1.4 *How was trust established and the requirements gathered?*

The Peruvian telecommunications corporation OSIPTEL wanted to extend the reach of broadband Internet into the rural communities, especially as telephone service was virtually nonexistent and impossible to install. An international agricultural aid organization called CGIAR wanted to help find a way to improve the output of the mountain potato farmers, so the potatoes would produce more vitamins. The group Organization Centro International de la Papa (The International Center for the Potato based in Lima, Peru) also wanted to improve the vitamin output of potatoes and to assist the villagers in learning where to sell their product. Between them, these organizations identified a few people to act as liaisons and project managers: Ruben Bustamante, a Peruvian with both college level technical training in computer network setup and maintenance and extensive experience in poverty alleviation projects, and Roberto Vargas (a pseudonym) a man well known to many of the project communities, with a strong reputation for fairness and sensitivity to racial and gender issues and reputable cultural values.

Beginning in April 2004 these Peruvian project managers and Logan Muller made several initial visits to talk with villagers about the potential project, to answer questions, address concerns, and most importantly: to find out what the people in each of the towns felt they needed. As part of this process, they located and recruited resident liaisons (locals) with a technical aptitude and an interest in taking part in the project. Logan rapidly developed a deep personal passion to apply his computing skills in helping the Andean population (Figure 1.4). Together, Logan and Ruben performed a town by town situational analysis, with Logan gradually becoming trusted as well. Logan spoke Spanish, which was very helpful; Ruben spoke the dominant native language Quechua, and thus acted as primary guide, driver, and translator in addition to his formal technical role. Their primary tactic, which could be taken almost verbatim from any good software engineering textbook, was to listen, listen, listen (Figure 1.5).

Each town had somewhat different issues to address, and a somewhat different demographic population. For example, some towns had large populations of single women who had escaped from terrorist attacks; other areas, at the highest elevations, were extremely spread apart and consisted mostly of potato growers, while yet other towns were populated primarily by alpaca ranchers. Each community would need a customized strategy for the makeup of the population, existing sub-groups, and the local social and political networks. Thus, the project managers and their local team spent days and weeks searching out local groups within each community to gather all their perspectives. Common

Figure 1.4 Logan's outdoor meeting with a group of Andean men. (Copyright, 1st July, 2011, Alison Clear and Logan Muller.)

Figure 1.5 Outdoor meeting against stunning backdrop. (Copyright, 1st July, 2011, Alison Clear and Logan Muller.)

among all the towns was the existence of a democratically elected mayor and a council. These officials were highly respected and made many decisions, although always in an open consultative way with input from the rest of the population. Overall, close to two years were spent talking to the villagers, asking clarification questions, taking notes, and recruiting local personnel. Alison Young, back in New Zealand, collaborated remotely via e-mail and Skype, providing technical advice and an external perspective.

What were the requirements of the villagers? As is often the case, the "client requirements" did not come in the form of technical information. It was up to the computer scientists to translate the villagers' needs into a workable proposal for a computing system, while checking each step of the way that their technical ideas were feasible in the harsh environment where they had to be implemented.

Summed up and paraphrased from their own words, the villagers asked to be provided the resources to:

1. Learn for themselves how to grow more nutritious potatoes.
2. Learn for themselves what was and wasn't a fair market price at any given time for their products when a buyer arrived.

3. Discover why their water was unhealthy and what actions they could take to address it.
4. Improve educational opportunities for their children.

The task of the project leaders was to take this information and turn it into a concrete set of requirements from which to develop technical specifications.

1.5 Organizing and itemizing final requirements

Most requirements revolved around designing a system that would create a communication network to address the human needs listed above. In addition, the system had to integrate into the existing communities rather than disrupt them. The unifying theme across all towns was a need to communicate with the outside world in order to obtain information.

Fortunately, the external stakeholders were fully committed to supporting some form of connection to the Internet in order to accomplish this goal. Keeping all this in mind, Ruben, Logan, and Alison (now in Peru), with input from their locally recruited volunteers (Figure 1.6), came up with the following list of requirements:

Figure 1.6 Alison and Logan hold a lunch meeting. (Copyright, 1st July, 2011, Alison Clear and Logan Muller.)

- A common high level framework must serve all the towns, for practical reasons of setup, training, and maintenance.
- Within the common framework, each town will need customization. Each town has different needs and cultural variations.
- All of the stakeholders within each town and nearby region must be accounted for. These stakeholders include: farmers, ranchers, displaced women, women and men in established traditional roles, teachers, and schoolchildren.
- The system needs to be developed in such a way that it will be essentially self-sustaining once it is installed, functional, and in use.
- Care must be taken to maintain and increase trust among all the stakeholders once equipment begins arriving and is installed, as there is the all too human inclination to provide preference to one group over another. Adhering to this requirement is particularly acute due to the prior exploitation experienced by the villagers from outside entities.
- Devise a way to address language and literacy barriers.
- Self-esteem issues are a big problem for women. How can the system especially support them?
- It is critical to design a system without losing sight of the strong sense of community coherence and reliance on one another—their central ethics and sense about how to survive.
- Installation and use of the computing system needs to not disrupt existing social systems and cultural values. It must support rather than change or undermine traditional culture.

Logistical requirements included:

- The remote location of the towns must be considered before deciding what equipment to purchase and how to transport it. The towns range from elevations of 10,000–15,000 feet (3,048–4,572 meters) and are miles apart from each other along dirt, boulder filled roads. Flight is impossible due to the terrain and expense. Ground vehicles must be used. However, having the equipment arrive in shattered bits and pieces must be avoided.
- Since most town councils are popularly elected by consensus, and along with the Mayors are highly respected, it is critical to obtain their full cooperation; they will oversee the centers where the computers will be set up and administered.

Technical requirements for an Internet-connected system included:

- Obtain a reliable satellite signal.
- Construct a network with sometimes inadequate supplies and equipment.

- Find and train additional local people to perform ongoing maintenance and to lead the educational efforts in each town.
- Recognize and compensate for the fact that in many areas it rains nine months of the year, which means there is extensive cloud cover and danger of equipment failure due to moisture.
- Be prepared to always think on your feet and improvise at a moment's notice. System reliability is critical and spare parts can take weeks to obtain.

As you can see, the technical challenges of designing and building the networks were created by the challenges of culture and geography. A system that would be simple in an urban location, or even a rural location closer to sea level, became a highly complex task when all contextual factors were taken into consideration.

1.6 Confirming the accuracy of the requirements with all stakeholders

A traditional western approach would be to draw up an itemization of the requirements just listed, and show it to all stakeholders for initial verbal approval. Then formal paperwork would be generated, and signed by selected representatives of the major stakeholders. Clearly, that approach would not work for this project. Even if most of the villagers could read and write, such an approach would fly in the face of culturally established methods of consensus based decision making.

Thus, Ruben, Logan, and their task force of local recruits spent many days revisiting the social groups that were discovered earlier in each community, repeating what they believed they had heard and having it either confirmed or changed (Figure 1.7). Many more very long and involved meetings took place so that everyone could have their say and reach agreement. Another benefit of this inventory of social groups was that the visits represented additional ways to get the word out about the opportunities of the project as it progressed. The villagers also took action, meeting among themselves in town meetings and council gatherings to further discuss their needs and seek consensus in between visits by the project leaders.

No formal written requirements documents were created, signed, or archived. This was absolutely necessary in order to function within the villages' cultural system. The project managers took virtually no notes during meetings. In private, they wrote meticulous notes about what they learned, and compared experiences among themselves as they visited with different groups. Primarily however, the project managers learned to work in an oral tradition. Agreements and changes

Figure 1.7 Alison and Logan listen to villagers discuss the project. (Copyright, 1st July, 2011, Alison Clear and Logan Muller.)

came about through dynamic conversations based upon mutual trust. Eventually, each community reached consensus about their requirements and the project managers moved on to developing the specifications.

1.7 Non-traditional specification development in the Andes

As with the requirements gathering, this stage of the project did not follow a traditional document and contract driven model. Nonetheless, it too followed the basic principles behind good specifications development, i.e., that the specification must describe "what" the system must do, based upon the requirements; the "what" then will lead to the "how."

In this case, the "what" had pretty much already risen to the surface based upon the carefully explored needs of all stakeholders. However, although the initial impetus for the project was to assist the potato farmers and alpaca owners, in reviewing the requirements, it had become crystal clear the "what" included educational, health, and psychological needs—that is if all users of the system (townspeople) were to be served and the population was to be helped to systemically reduce their poverty levels.

The outside stakeholders, New Zealand AID, OSIPTEL and the CIP were satisfied as long as visible progress was being made. They all recognized the process would need to be a slow one if it were to succeed for the long term.

ACRONYMS OF THE MAJOR EXTERNAL STAKEHOLDERS

OSIPTEL—Peruvian Telecommunications Corporation
CGIR—An International AID Organization
CIP—The International Center for the Potato
NZAID—New Zealand Agency for International Development
GILAT—Internet Service Provider for the Andean villages
Unitec—the Institute in Auckland, New Zealand where Logan and Alison worked
CIC—Centers for Information and Empowerment. The physical locations where computers were set up in each village.

Note: Links to organizations are in the Appendix

1.8 *Specifications: Social, cultural, technical implementation intertwined*

The project took place in two regions: Huancavelica and Apurimac. Recall there were 11 towns involved in the project. Two towns were in Huancavalica (Daniel Hernandez and Colcabamba) and nine towns were in Apurimac including: Antabamba, Totora, El Oro, Pachagonas, Huarquirca, Sabarino.

A common fundamental technical requirement for all 11 towns was obtaining a reliable satellite signal for establishing Internet connections. Without a reliable signal Internet access would be unpredictable and the system unusable for the very busy villagers. Each user was going to take time out of their already full day to walk to the computers and use them. Thus the proper angle of each town's satellite dish was critical. Eutelsat (a satellite system over Europe that covers Latin America) was the cheapest alternative, but the placement of the satellite relative to the location of the towns and their satellite dishes would create unreliable connections. The angle of attack for Eutelsat was a very low 17 degrees, which was even more problematic given the weather conditions of frequent rain, snow, and electrical storms (Figure 1.8). Conversely, SatMex5 (a satellite system over Mexico) cost more but had better placement for the Andean mountain locations. SatMex5 was selected. The current state of the art low frequency broadband wireless used in cities (Wimax at 800 MGhz), was either not available or affordable in the Andean towns. Therefore, the older but well

Figure 1.8 Satellite dishes were installed at the best angles. (Copyright, 1st July, 2011, Alison Clear and Logan Muller.)

established 2.4 Ghz wireless was used, thereby guaranteeing easier access to good service and reliable information. The Internet Service Provider was GILAT Network Systems.

As predicted in the requirements list, the computer scientists and their team had to think creatively to make many technical things work. For example, in Daniel Hernandez, there was initially a problem trying to find the correct focal point for aligning a satellite dish. No satellite dish was yet available, but the information was needed as part of the decision about which satellite system to use. Improvising, they built a home-made dish to link two offices together. They started with an antenna they could obtain fairly cheaply. Then they lined a Chinese wok with aluminum foil and used its reflectivity to locate the focal point using the sun (Figure 1.9). They next placed a USB wifi receiver on the end of a piece of rubber hose right at the focal point and used this to transmit the wireless back and forth across the town, to a distance of 1.24 miles (2 kilometers).

There was another common requirement: the fairly homogenous set of activity needs centered on communication and education. Therefore, virtually the same equipment was selected and installed in each town. Each machine was a Pentium 4 with 512 Mg RAM and, on average, a 40G hard drive. Each user machine ran Windows XP. These machines were easy to obtain in Lima, and in case of disaster (such as losing some parts over the side of a ravine as they bounced up the narrow mountain roads), replacement parts could be obtained down the mountain. Fortunately, due to very careful packing and good luck, this problem did not arise and all the machines arrived intact.

Figure 1.9 The famous wok satellite dish. (Copyright, 1st July, 2011, Alison Clear and Logan Muller.)

The software installed on the machines was Microsoft Office (in Spanish), the Internet Explorer browser (in Spanish), and e-mail. These software packages were chosen because they were easy to obtain and provided a well known standard platform. The first three applications would enable all users to perform searches and make inquiries about what they needed to know. In addition, an educational set of software, including children's programs and adult Spanish lessons, was donated by a company called SkillSoft. The educational software had previously been used by Unitec in New Zealand for five years as part of community outreach efforts. Those efforts had targeted large, non-traditional groups of users, and thus the project leaders felt confident this particular product had been sufficiently "road tested." Language software would address the literacy problem: more villagers needed to learn to read and write Spanish in order to understand and communicate with the cities and towns down the mountains.

Centers were set up in each participating town, with three main centers in Daniel Hernandez, Colcabamba, and Antabamba. The remaining eight towns served initially as annex centers. The eleven centers were called *"Centros de Informatión y Capacitación"* (CIC for short) or in English,

Figure 1.10 One of the CICs. (Copyright, 1st July, 2011, Alison Clear and Logan Muller.)

"Centers for Information and Empowerment" (Figure 1.10). The name was chosen deliberately, as one part of an overall plan to send the message that these computing centers were there to help the people help themselves. As part of this same plan, and to continue addressing issues of trust and communication identified in the requirements, each town trained its own educator-trainers, who themselves had been initially trained by project managers Ruben, Logan, and Alison.

Training local personnel in the software applications, the operating system, hardware and networking was an important component for ensuring not only acceptance of the project, but for ensuring the requirement for long term sustainability of the systems. For the most part, the initial educator-trainers were the same people who had been recruited early on by the project managers to act as liaisons to their towns. People were chosen to be onsite maintenance personnel and/or trainers based upon their prior experience in some technical area, or if they showed an aptitude or even just the desire to learn the details of their town's new system. The "job description" was fairly simple, relying mostly upon a demonstrated interest and dedication to the project, rather than unrealistic prior education. Training was not a one-time activity, but an ongoing event, as new people brought in other people and helped them learn. Thus, knowledge and use of the system spread outward in an ever widening circle through the community, enabling more and more people (farmers, women, teachers etc.) to become independent users. This too, was part of the plan to fulfill the requirement to support and align with historic community values of interdependence and sharing.

1.9 Requirements that led to customization

Not all of the towns were initially connected to the Internet. In the Huancavelica region, the central CICs at Daniel Hernandez and Colcabamba were the first to be connected to the Internet, using an ADSL connection as follows:

ADSL copper link → a Linux server → 20 machines (Colcabamba)

In the Apurimac region, the central CIC at Antabamba was connected in similar fashion and a local wireless LAN was set up to connect the library and medical center to one another and the CIC.

The eight annex centers were not initially connected to the Internet, but provided with six to ten computers, Microsoft Office, and educational software. This setup was used to train people on individual computer use and maintenance, word processing, and spreadsheets, and for educational activities in between people's opportunities to visit the primary CIC in Antabamba. Later on, two of the annex centers were connected to the Internet by OSIPTEL. VOIP was then used to communicate between Antabamba and Huaquirca, enabling the villagers to work around the non-existent or unaffordable telephone service.

1.10 Rapid results and concrete outcomes

The initial target audience, the potato farmers, immediately began using the computers at night to research how to grow potatoes with higher vitamin yield, and thus help address the serious malnutrition problem. In addition, these farmers were able to look online daily to see what the current market prices for potatoes was in the city, so that when buyers unexpectedly appeared on the mountain they were prepared to bargain effectively (Figure 1.11). Finally, the farmers communicated with CIP (The Center for the Potato), receiving advice from their specialists and participating remotely in CIP sub-initiatives. The success of the potato farmers' activities was crucial because this part of the project was what started the entire poverty alleviation effort by the Peruvian Ministry of External Relations and NZAID.

Ranchers, who were sometimes also potato farmers, went online and learned about market prices for other goods they had available such as alpaca wool, and which were in demand in the city. In addition, they learned online about new ways to perform various tasks, such as more efficient ways to shear the alpaca wool using scissors instead of knives. Many ranchers lived far from the town and through participating in the CIC project they came to feel more connected to their community.

Teachers utilized the computers by bringing their students to use them when other people were not using them. Besides using the Skillsoft

Figure 1.11 Two users show their opinions of the system. (Copyright, 1st July, 2011, Alison Clear and Logan Muller.)

educational software for traditional educational activities, both the teachers and the children were able to learn skills that would help them succeed better in the twenty-first century, whether they intended to stay in the towns or move to a city. These software programs were so popular that students in remote towns without teachers or schools sometimes walked several hours in order to get to a CIC center to study (Figure 1.12). The teachers were one of the most vocal groups frequently asking if more computers could be obtained and dedicated to the schools, or if they could have more time on the computers in the centers.

Self-esteem issues that existed for many women, especially those who had been displaced in the past by terrorism were addressed as well. Traditionally, women stayed at home, and they had told the project managers early on they wanted to contribute more to their community. Once the CICs were set up, many women went online during the day while their children were either at school or under a friend or family member's care. They learned many basic skills, such as how to read and write in Spanish, and how to use basic Internet functions such as a browser. From there, they were able to begin their own research into issues their community needed (Figure 1.13).

Women's groups had some particularly impressive successes as a result of using the CICs. For example, one group of women located a promising grant opportunity; they applied for it and were awarded funding. These funds and the information resources that came with