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ABSTRACT

This document is an exploratory study of issues and evidence related to academic skills, nonacademics, and work along three lines of inquiry. Section 1 is an introduction that explains the three lines of inquiry: literature review to identify empirical studies and salient issues pertinent to academic skill needs; new analysis of existing data from a previous study of seven technical jobs; and analysis of existing longitudinal survey data on high school students to define different types of skills and example their relationship to a variety of postschool outcomes. Section 2 discusses the literature on the following: skill and ways of measuring it; skill transfer; definition/redefinition of the disciplines; situated learning; and the value of academic skills. Section 3 examines mathematics, science, and technology skills in seven technical jobs. Section 4 is a quantitative analysis of existing longitudinal data sets regarding the need for academic and nonacademic skills in the labor market and the value of extracurricular activities and labor market work while in school. Section 5 is a summary. The report contains 91 references and 14 tables. Appended are scenarios demonstrating the application of workplace skills in practice and information about the data samples and variable definitions. (MN)

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National Center for Research in
Vocational Education

University of California, Berkeley

# Academic Skills at Work: Two Perspectives

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Dominic J. Brewer
RAND







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# Preface

Changes in work continue to raise questions for employers, educators, and policymakers about the kinds of skills and competencies that young people need in order to succeed in work and further education, especially right after high school. As a result, many recent efforts have begun to reconceptualize skills in ways that potentially expand the content and range of learning experiences that are afforded to high school students. Important issues arise concerning the emphasis of academic skills, the mainstay of the high school curricula, over non-academic skills and work-related competencies.

This exploratory study examines issues and evidence related to academic skills, non-academics, and work along three lines of inquiry. A literature review highlights issues and conceptual dilemmas that arise from different perspectives on skills. Two new data analyses, each from a different perspective, examine some important relationships between skills and work. In addition to this technical report, a companion piece will synthesize these findings for a practitioner audience.

This research was supported by the National Center for Research in Vocational Education (NCRVE), University of California, Berkeley, with funding from the U.S. Department of Education. It was conducted within the RAND Education Program, under the directorship of Roger Benjamin. The study is one of a series of projects conducted by RAND researchers for NCRVE on skill changes in work and the implications of those changes for education policy and practice.

# Acknowledgments

Several individuals contributed to this report: Tessa Kaganoff helped with the literature review, Joy Goodwin and Stephanie Williamson contributed to the quantitative data analysis, Edie Nichols and Donna White helped prepare the manuscript, and Stephen Billett and an anonymous reviewer provided thoughtful and useful technical reviews of the initial draft. We thank all for their contributions.

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# Executive Summary

## *Introduction*

It is now commonly accepted that changes in work and the workplace are transforming the kinds of knowledge, skills, and attitudes needed for successful work performance. Evidence for new skill needs from employer surveys, for example, suggests that employers are often more concerned about soft skills or attitudes rather than technical knowledge or competencies. Empirical studies of work find that employers and workers also feel generic skills, such as problem solving, communication, and the ability to work in teams, are increasingly important for workplace success (Stasz, Ramsey, Eden, Melamid, & Kaganoff, 1996).

In recognition of changing skill demands, new frameworks for defining work skills and competencies have been developed in the U.S. as well as in other countries. The Secretary's Commission on Achieving Necessary Skills, for example, introduced a two-part framework: workplace competencies, such as interpersonal skills, familiarity with technology, or ability to manage resources; and foundation skills, including the basic skills of reading, writing, arithmetic, and mathematics. These efforts to define new skills often pay little attention to academic skills and do not delineate relationships among academic skills, work competencies, or soft skills. Furthermore, in the process of redefining skills, we have not yet reached consensus on terminology or definitions for the variety of skills deemed important.

The feeling that new skills are required for work has motivated some important shifts in thinking about how to best prepare young people for education and work after high school. Educators and school reformers are updating curriculum or redesigning school programs as a way to ensure that young people have opportunities to learn work-related competencies in addition to academics. Despite the interest in supporting students' development of work-related skills and attitudes, the traditional academic curriculum remains the mainstay of high school education, and many school reforms emphasize improvement in academic subjects.

The desire to raise academic performance and, at the same time, to provide opportunities for students to acquire other competencies creates substantial challenges for educators. Expanding the curriculum to better meet new skill demands raises some challenging questions: What should the high school curriculum look like? How can we teach problem solving and teamwork in English, social studies, and mathematics? To what extent can we incorporate demands for new skills without watering down the academic curriculum? Should we increase participation in service learning or work-based learning to enhance work-related skill development?

Answering these questions requires understanding the complex relationships between academic and non-academic skills and work.

To begin to outline these relationships, we conducted a one-year exploratory study along three lines of inquiry. We reviewed the literature to identify empirical studies and salient issues in the discussion about academic skill needs and any empirical research that sheds light on academic skill demands. Second, we carried out a new analysis of existing data from a previous study of seven technical jobs (Stasz et al., 1996). Finally, we analyzed existing longitudinal survey data on high school students to define different types of skills and to examine their relationship to a variety of post-school outcomes. By pursuing these three lines of inquiry, we hoped to provide some information about the type and level of academic skill demand requirements in work and also to help frame future discussion and research on this topic.

This study is not intended to yield a comprehensive or generalizable set of answers. The analyses conducted here made use of existing data sets which constrain the analytic task itself and the generalizability of findings. Thus, the study examines academic skills within certain tracks of the labor market and certain student groups. Even with these constraints, we believe the analyses yield new and useful information on relationships between academic skills and work.

The base premise of our approach is that skills are most appropriately viewed as multivariate. In the popular literature, a multivariate view of skills is perhaps best encapsulated in Howard Gardner's (1993) writing about multiple intelligences. He defines seven intelligences: the linguistic and logical-mathematical intelligences that are at such a premium in schools today; musical intelligence; spatial intelligence bodily-kinesthetic intelligence; and two forms of personal intelligence, one directed toward other persons, one directed toward oneself (p. xi). The notion that skills need to be viewed as multivariate is supported in all three strands of the research presented here.

## *Themes from the Literature*

Several different literatures speak to the nature of skill needs at work, but none is completely satisfactory for understanding skill requirements. The research is also limited with respect to generating specific guidance that is useful to educators. Thus, any review of the literature on the relationship between academic skills and work is unlikely to provide definitive answers.

Overall, our review of the literature reveals much tension and underlying controversy that shapes the debate about skills, and several important themes and issues. First, the definition of academic skills is debatable. Two theoretical perspectives dominate the study of skills at work and sometimes yield conflicting results or policy recommendations. The positivist perspective conceives of skills as unitary, measurable traits of individuals and holds strong assumptions about a person's ability to transfer skills from one context to another. The situative perspective assumes that skills are larger than an individual's behavior and cognitive processes. Individuals act in social systems that partly determine skill requirements, distribution of work, and other factors. From this perspective, direct transfer of skills across settings is rare. Neither the positivist nor the situative perspectives, however, provide a complete picture of the place of skills at work.

Educators grapple with changing skill needs in various ways. The literature indicates that curriculum in academic disciplines is becoming more interdisciplinary and is placing more emphasis on the application of academic knowledge to solve real problems. Educators search for relevant applications or problem situations that will engage students and also help them understand underlying academic concepts. They see value in project-based learning activities, in providing learning experiences outside of classrooms, and in making more explicit connections between school and work. Many see value in applied or contextualized learning, but find it difficult to identify or import out-of-school examples into a school-based learning context.

In general, employers seem less concerned about academic skills. They want employees who are literate and numerate, of course, but in making hiring decisions they tend to value more highly an applicant's work-related attitudes, communication skills, and previous work experience over school-related factors (e.g., grades, degree, or certification).

## *Academic Skills in Technical Work*

The second strand of the study examines academic skills in the context of seven, sub-baccalaureate technical jobs in four industries: traffic signal technicians in a traffic management agency; home health aides and licensed vocational nurses in a health care agency; test and equipment technicians in a microprocessor manufacturing plant; and construction and survey inspectors at a transportation agency. The case studies and analysis of these jobs followed the situative approach and assumed that skills must be viewed from the perspective of individuals in the working community. A previous study of these same jobs focused on generic skills—problem solving, communications, and teamwork—and on work-related attitudes (see Stasz et al., 1996). This new analysis emphasized application of mathematics, science, and technology in these occupations.

This analysis yielded several interesting findings:

1. Technical work incorporates a wide variety of mathematics skill levels, ranging from basic mathematics (pre-algebra) to complex trigonometry.

2. Mathematics, science, and disciplinary knowledge varies with work context. In some cases, work is dominated by a few disciplines or subject areas, while other work may require broad disciplinary knowledge.

3. Technical workers may not discuss academics in the terms typically used in school, but in relation to a particular work process or technology application.

4. In some communities of practice, it can be important to establish the precise meaning of terms related to math or science applications because individuals within a community can define important concepts in different ways.

5. Technology-in-use may define work practice and academic skill requirements.

6. Managers' and supervisors' understanding of academic skill requirements appear consistent with frontline workers' own estimation. This finding departs from our previous study of generic skills, where employers and workers often disagreed about capabilities related to problem solving, communication, and other soft skills.

## *Skills and Labor Market Performance*

The third strand of the study explored relationships between academic skills, non-academic skills, and labor market performance from the positivist perspective. However, in a departure from that perspective, it adopted a multivariate view of skills in its analytic approach. This analysis utilized existing individual-level longitudinal data on the high school classes of 1982 (High School and Beyond [HSB]) and 1992 (The National Educational Longitudinal Study of 1998 [NELS:88]). In addition to standard measures of academic skills (e.g., grades, achievement test scores, and years of schooling completed), information about extracurricular activities and part-time work served as proxies for non-academic skills. For example, participation in extracurricular activities, such as sports teams or band, may provide students the opportunity to develop social and teamwork skills.

The analysis first looked at relationships among skills and found a modest positive association between academic skills and extracurricular activities. The analysis revealed a negative association between hours of part-time work in high school and academics, and, to a lesser extent, between hours of part-time work and extracurricular activities. While no causality can be inferred, the results do suggest that academic measures alone are unlikely to adequately capture the multifaceted skills individuals take to the labor market.

Simple wage regressions for those high school students who enter the labor market directly after high school suggest that academic indicators have little impact on early career (two years after high school) labor market success. Extracurricular activities are also unimportant for this group of students. Previous work experience, however, is important: Students who worked more during high school earn marginally more once they enter the labor market after high school. If this preliminary work holds up, it suggests that work-based learning experiences may be especially important for students not immediately bound for college.

## *Conclusions*

This exploratory project examined relationships between academic and non-academic skills and work. Educators, employers, and policymakers are interested in academic skills for several reasons, chief among them is the concern that changes in work require different preparation in school if youth are to make a successful transition to employment. The literature review highlighted two perspectives for studying skills and identified some issues in the debate about defining and measuring skill requirements and incorporating these skills in school programs.

Two separate analyses examined skills from different perspectives, while sharing the view that skilled behavior is multivariate. The detailed case studies of seven technical jobs demonstrate how academic skill requirements are contextually bound. Academic skills are always used in some applied context—technicians use algebra for a purpose, not just for the sake of solving algebra problems.

The situated nature of academics has implications for educators. Instead of viewing academic knowledge as archetypes, it may be preferable to accept that knowledge is transformed by application in different kinds of social and cultural practices. The challenge is to design learning tasks or environments that first of all reflect the potential uses for the knowledge being taught.

Technical work may regularly utilize high-level mathematics and scientific knowledge. Academic skill needs are also connected with specific technologies utilized in various jobs. Technology education should make explicit connections to academic skills and, above all, promote an understanding of why a particular technology application works. Instruction must go beyond teaching manual skills needed for operating machines or tools.

The quantitative analysis of skills and job performance has less to say about teaching specific skills, but does suggest that work experience in high school has some payoff above academic performance. This analysis, the literature review, and the case studies of technical work all demonstrate that employers highly value work experience in making hiring decisions.

Taken together, the results from this project are intriguing but far from conclusive. To further explore the multivariate relationships among skills and to sort out the relative importance of education versus experience in rewarding labor market performance, we need much better information about types of jobs and more reliable data on non-academic skills from a larger number of individuals.

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CHAPTER 1

# Academic Skills at Work

## *Introduction*

It is now commonly accepted that changes in work and the workplace are transforming the kinds of knowledge, skills, and attitudes needed for successful work performance. Evidence of the need for new skill comes from many sources, including the National Employer Surveys conducted by the National Center on the Educational Quality of the Workforce (NCEQW) (1995) and from a small but growing body of empirical research on work (e.g., Barley & Orr, 1997; Hull, 1992; Stasz, Ramsey, Eden, Melamid, & Kaganoff, 1996). The research indicates that employers are often more concerned about "soft" skills or attitudes rather than technical knowledge or competencies. They seek employees with the right attitudes and dispositions toward work—individuals who are motivated, honest, responsible, reliable, willing to learn on the job, and willing to take responsibility for their own learning. Employers and workers also note the need for "generic" skills such as problem solving, communication, and the ability to work in teams (Stasz et al., 1996).

In recognition of changing skill demands, policymakers and others have been developing new frameworks for defining skills that incorporate but go beyond the traditional high school menu of courses to develop academic or job-specific vocational skills. The Secretary's Commission on Achieving Necessary Skills (SCANS) (1991, 1992), for example, introduced a two-part framework: (1) workplace "competencies" such as interpersonal skills, familiarity with technology, or ability to manage resources; and (2) "foundation skills," including the basic skills of reading, writing, arithmetic, and mathematics. The federal government is supporting the development of skill standards in 22 industries. These efforts to define new skills do not always discuss academic skills and standards in much detail, nor do they delineate relationships among academic skills, work competencies, industry-specific skill standards, or work disposition and attitudes.

In the process of redefining skills, we have not yet reached consensus on terminology or definitions. The term "academic skills" is generally associated with subject-matter areas defined by the various school disciplines such as English, mathematics, history, science, and so on. Knowledge about those subjects is primarily learned in school and is expected to be broadly transferable to situations and circumstances outside school.

Work competencies, or "generic skills" as defined by SCANS and others, are thought to be broadly transferable across work settings, although they can take on different meanings in different contexts. Problem solving, for example, is a general term that represents a particular competency, but the process itself varies with different tasks or situations. Without attention to context, terms like "problem solving" or "communication" are rendered meaningless, especially as definitions of what should be taught in classrooms (Stasz, 1997).

Industry standards refer to skill requirements specified in a particular industry and may refer to academics (e.g., math knowledge needed by surveyors) or to knowledge about certain tools or processes (e.g., operation of an x-ray machine). The actual skills needed depend on a particular work context.

Work attitudes or dispositions are perhaps the most difficult to define, as there is no accepted way to conceptualize them. The term generally refers to any "non-cognitive" factor that can affect learning and performance and includes such constructs as motivation, volition, and disposition (Stasz et al., 1996; Stasz, 1997).

The feeling that new skills are required for work has motivated some important shifts in thinking about how to best prepare young people for education and work after high school. Educators and school reformers are updating curriculum or redesigning school programs at all levels as a way to ensure that young people have opportunities to learn work-related skills and attitudes in addition to academics. Reformers also increasingly perceive that all students, not just those destined for traditional vocational programs, can benefit from approaches that change both the content and process of learning.

Despite the interest in supporting students' development of work-related skills and attitudes, the traditional academic curriculum remains the mainstay of high school education. In the decade following the publication of *A Nation at Risk* (National Commission on Excellence in Education, 1983), many states increased the academic requirements for high school graduation. In 1982, only 13% of high school graduates had completed a core curriculum of four years of English, three years of social studies, science, and math; by 1992, 47% of graduating seniors had taken this coursework (Jennings, 1996). Over the same time period, enrollments dwindled in vocational programs, through which students are most likely to have opportunities to learn work-related skills and competencies.

The desire to raise academic standards and, at the same time, to provide opportunities for students to acquire other competencies creates substantial challenges for educators. It requires some reconciliation between the teaching of academic subjects and of work-related skills and competencies. Expanding this curriculum to better meet new skill demands raises some challenging questions:

- What should the high school curriculum look like?

- How can we teach problem solving and teamwork in English, social studies, and mathematics?

- To what extent can we incorporate demands for new skills without watering down the academic curriculum?

- Should we increase participation in service learning or work-based learning to enhance work-related skill development?

Answering these questions requires understanding the complex relationships between academic and non-academic skills and work.

To begin to outline the relationships among academics, work-related skills, and work, we conducted a one-year exploratory study along three lines of inquiry. We reviewed the literature to identify empirical studies and salient issues in the discussion about academic skill needs and any empirical research that sheds light on academic skill demands. Second, we carried out a new analysis of existing data from a previous study of seven technical jobs (Stasz et al., 1996). Finally, we analyzed existing longitudinal survey data on high school students to define different types of skills and to examine their relationship to a variety of post-school outcomes. By pursuing these three lines of inquiry, we hoped to provide some information about the type and level of academic skill demand requirements in work and also to help frame future discussion and research on this topic.

This study is not intended to yield a comprehensive or generalizable set of answers. The analyses conducted here made use of existing data sets which constrain the analytic task itself and the generalizability of findings. Thus, we can only examine academic skills within certain tracks of the labor market and certain student groups. Even with these constraints, we believe the analyses yield new and useful information on relationships between academic skills and work.

The base premise of our approach is that skills are most appropriately viewed as multivariate. In the popular literature, a multivariate view of skills is perhaps best encapsulated in Howard Gardner's (1993) writing about multiple intelligences. He defines seven intelligences: "the linguistic and logical-mathematical intelligences that are at such a premium in schools today; musical intelligence; spatial intelligence; bodily-kinesthetic intelligence; and two forms of personal intelligence, one directed toward other persons, one directed toward oneself" (p. xi). Although the analyses in Chapters 3 and 4 may not appear to have a lot in common, they both share this important perspective.

In conducting this exploratory study, our goal was to provide information and analysis that is useful to a wide variety of audiences: curriculum developers and teachers who need to make decisions about the scope of the curriculum and the relative emphasis on different subjects; teachers interested in developing problem-based curricula and activities that apply academic knowledge in meaningful ways; policymakers at different levels faced with curriculum-related decisions that affect the general shape of the curriculum, particularly at the high school level; employers who partner with schools and educators to develop alternative education programs; and researchers who study relationships between skills and school or employment outcomes.

This report is organized into five chapters. Following this introduction, Chapter 2 discusses the literature review and frames salient issues and research findings about academic skills at work; Chapter 3 examines mathematics, science, and technology skills in seven technical jobs, following the same approach as our initial investigation of "generic" skills in these occupations; Chapter 4 reports on the quantitative analysis of existing longitudinal data sets; and Chapter 5 summarizes themes and findings across the three strands of the study and discusses implications for future work.

CHAPTER 2

# Academic Skills at Work: A View from the Literature

Several different literatures speak to the nature of skill needs at work. A recent review by Berryman (1993) organized these literatures along the five methods used to identify skill requirements: (1) surveys of employers (or employees), (2) case studies of firms and industries, (3) ethnographic studies of work, (4) job analysis methods, and (5) analyses of trends in variables treated as indicators of changes in skill supply or demand (e.g., changes in wage returns to different levels of education). A comparison of these methods in terms of their reliability and validity, generalizibility, and usefulness for generating trend data that informs the direction of skill requirements suggests that, *on their own*, none of the methods is completely satisfactory for understanding skill requirements. The research is also limited with respect to generating specific guidance that is useful to educators. Thus, any review of the literature on the relationship between academic skills and work is unlikely to provide definitive answers.

For the purposes of this investigation, we sought empirical research about academic skills, work, and research that provides some insight for education practice. Most of the empirical research of interest is found in ethnographic studies of work, and some evidence is provided in survey data or studies of indicators of skill change. These three literatures are quite divergent in the basic assumptions held about skills and skill development. In addition, arguments for or against skill change or for how to remedy skill supply problems often rely on untested assumptions or long-held beliefs about curricula and schooling. Overall, our review of the literature reveals much tension and underlying controversy that shapes the debate about skills, including the interpretation of research on skill changes and the implications of that research for education policy and practice. In order to do justice to the topic, it is important to describe these controversies. The following review, then, is not a straightforward summary of the literature but a broader discussion of themes and issues concerning academic skills and work.

## *What Is Skill, and How Do We Measure It?*

The very definition of "academic skill" is debatable. Attewell (1990) discusses four different conceptions of skill, two of which are particularly central to this discussion.[1] Briefly, the positivist perspective treats skill as an attribute that is amenable to quantitative measurement and has objective character independent of the observer. In assessing skill, positivists may treat it as a measurable attribute of a person—as in a test of verbal or quantitative skills—or as an attribute of a job or task—as in a job analysis. Academic skills are largely viewed as measurable properties of individuals, as evidenced by the preponderance of testing in schools to indicate that students have learned or achieved some skill level. Testing done in a work setting has a similar objective: To measure whether a person has the skills believed necessary for a particular job. Task or job analyses are used to determine what skills are required in order to develop those entry tests or to help sort job incumbents. In general, positivists take the view that individuals and jobs can be adequately characterized by defining a discrete set of skills (either in the person or required in the job) and then matching individuals to jobs based on skill profiles for each (Darrah, 1992). The positivist view is evident, for example, in research that measures the relationship between academic skills and wages (e.g., Murnane, Willett, & Levy, 1995) and more generally in the widely adopted notion of human capital (Becker, 1962). Chapter 4 discusses these type of studies in more detail.

An alternative to positivism is found in ethnomethodological or situative perspectives (e.g., Greeno, 1998; Resnick, 1991; Rogoff & Charajay, 1995; Scribner, 1984). The situative perspective shifts the focus from individuals to interactive systems or social settings that are larger than the behavior and cognitive processes of a single person. The social setting in which cognitive activity takes place is an integral part of that activity and not simply the surrounding context for it. The knowledge, attitudes, or abilities needed for a certain job can be understood only within that particular working context—that is, from the perspective of the individuals in the social setting. The context can include other actors, the task at hand, the organization of the work, the physical or symbolic systems that comprise the job, and so on. Numerous studies have examined skills in specific occupations from this perspective.[2]

Neither the positivist nor situatative perspectives alone are adequate for answering the range of questions concerning academic skill

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[1] Also see Spenner (1990), Vallas (1990), and Darrah (1992) for further discussion about defining and measuring skill and skill requirements.

[2] For example, hairdressers (Billett, 1996); secretaries (Hart-Landsberg, Braunger, Reder, & Cross, 1992); product assemblers and wholesale drivers (Scribner, 1984); traffic-signal technicians, construction and survey inspectors, home health aides, and licensed vocational nurses (Stasz et al., 1996); circuit board assemblers (Kleifgen & Frenz-Belken, 1996); CNC machiners (Martin & Beach, 1992); and various technical jobs (Barley & Orr, 1997).

requirements and work (Berryman, 1993). Ethnographic studies provide rich examples of skills at work that can be useful to education practitioners, but they are limited in generalizability and typically do not measure productivity or other outcomes. Limitations in the positivist approach are outlined further in Chapter 4.

Research from these different perspectives can yield contradictory implications for practice or policy. Studies of changes in labor market returns to different education levels, for example, show an increasing payoff in terms of a college education during the 1980s, caused by changes in both skill supply and demand (Murnane & Levy, 1996). In these studies, "education" is a proxy for "academic skill"—higher levels of skill are better.

In contrast, ethnographic studies of work, which actually observe what people do on the job, have found that while formal knowledge—acquired in school—plays a role in job performance, it is often much less important than "working knowledge"—knowledge and skill derived from experience. Studies of technicians with different credentials, for example, show that the ability to detect errors in medical procedures is unrelated to level of credential (Scarselletta, 1997). Thus, although the credentials a technician holds are tied to his or her wages, wages are not necessarily a valid indicator of performance on the job.[3]

## *The Issue of Skill Transfer*

Educators and policymakers devote a lot of time deciding what to teach—what content and courses to include in formal education. It is generally accepted that mandatory schooling should impart some basic knowledge and skill that will serve as the foundation or building blocks for future learning in school and life. Basic skills are defined in various ways but usually refer to the three Rs—reading, 'riting, and 'rithmetic—and other academic disciplines. As mentioned earlier, high school graduation requirements emphasize basic academics, as do the various "back to basics" reforms. Recent studies attempt to define the basic academic skills that schools should teach to prepare students for the changing work world. Murnane and Levy (1996), for example, define the "new basic skills" or the minimum skills people now need to get a middle-class job. Their list includes "the ability to read at the ninth-grade level or higher" and "the ability to do math at the ninth-grade level or higher" (p. 32).

Whether the discussion is about old skills or new, basic or advanced, an implicit assumption is the notion that school learning (or at least some

[3] Economists have acknowledged the role of on-the-job training, but it is difficult to measure the true extent to which skills are acquired on the job in any systematic way (see Barron, Berger, & Black, 1997). Further, in the long run, in a competitive market, job performance must be reflected in wages.

essential elements of it) transfers to other contexts. The idea that skills transfer from the context in which they are learned to a new situation follows logically within the positivist and human capital framework. Skills are discrete entities that a worker can acquire and, over time, they will increase the stock in that person's repertoire. The knowledge and skills students learn in high school should be useful in further schooling or be applicable in work situations. Therefore, if one knows what skills are required in work, the school should be able to design curricula to ensure that students acquire the proper building blocks.

Transfer has been cited as a justification for changing curricular content. Countless discussions of curriculum reform, led by educators and employers alike, argue that students need to learn new skills because work changes demand them. On the academic side, for example, researchers cite changes in work to justify the content of the mathematics curriculum (e.g., Murnane & Levy, 1996; Steen & Forman, 1995). On the vocational side, transfer is the rationale for broadening vocational education from specific job training to education in "all aspects of the industry." All these efforts assume some mapping between skills learned at school and their application on the job.

The transfer assumption is also evident in policies that require specific degrees or course taking in a relevant discipline in order to obtain a license or certification to practice a particular occupation. In the case of technical work, for example, the claim is made that effective technical practice relies heavily on theoretical or abstract knowledge, and technicians should therefore obtain degrees from postsecondary institutions in a relevant discipline (Barley & Orr, 1997). Theoretical, abstract, or "formal" knowledge is dispensed in school, and it is this "pure" knowledge that presumably transfers to non-school activities. Ethnographic research on work, however, suggests that formal knowledge typically plays a small role in what enables workers in many fields to successfully confront the ambiguities of practice (see Pinch, Collins, & Carboni, 1997; Scarselletta, 1997).

Many studies, largely from the situated perspective, raise serious questions about transfer. These studies suggest that simple one-to-one transfer does not happen very often or identify basic differences between formal knowledge and knowledge as applied in context which make simple notions of transfer hard to rationalize (Lave, 1988; Rogoff & Lave, 1984; Scribner, 1984, 1988). Vygotsky (1978), for example, pointed out that physical objects instrumental to the tasks that individuals accomplish in a given context, over time, become part of a person's mental operations. Scribner's studies of mathematics at work illustrate his point. In her study of dairy workers, for example, Scribner (1984) documented multiple ways in which these workers used knowledge of milk case size and physical space to make their work more efficient. They did few calculations that are recognizably arithmetic—as defined by school mathematics—but got reliable results by treating the material they worked with as part of their calculation. This line of research complicates the question of what is transferred because the abstract, formal operations in mathematics are mediated by the instrumental physical objects of the environment (e.g., the milk case) (Alterman, Wolf, & Carpenter, 1998).

Carraher and his colleagues (Carraher, 1991; Carraher, Schliemann, & Carraher, 1988) provide other evidence that practical and formal knowledge may be substantially different. In a study of Brazilian children who worked as street vendors, for example, the researchers found differences in the children's success at solving similar mathematics problems presented in different ways. While children solved 98% of problems given in the street setting, their success rate dropped to 34% when the same problem was presented as a computation (e.g., How much is 35 times 10?). Further studies show that given a choice, children are more successful at solving problems in their head (which they termed "oral maths") than solving them with "written maths," algorithms learned in school. These studies of cognitive mathematics outside of the school setting show that even unschooled children and adults routinely perform mathematics calculations at work, in naturally occurring situations.

Although these studies do not negate the value of mathematical algorithms, they raise questions about the viability of the "mathematical toolbox" which students develop in school then carry with them in life outside school, in the home, and in the factory (Dowling, 1991). More generally, these studies call into question the premise that any academic learning in school will be transferred directly to the workplace (Darrah, 1992).

## *Defining and Redefining the Disciplines*

Educators continually redefine the academic disciplines, whether or not they invoke transfer as a rationale for doing so. Although the academic curriculum still holds sway in most educational institutions, there are signs that sharp boundaries within the academic disciplines and even between academic and vocational programs are beginning to blur. Within academic curricula, for example, we see a growing number of interdisciplinary courses that either blend separate academic strands (e.g., English and social studies) or reflect a more integrated approach to a subject matter (e.g., integrated science courses, which combine biological and physical sciences or "systems"). Similarly, within academic disciplines, there is interest in creating curricula that emphasize application or "doing" in addition to "knowing." These shifts within academic disciplines seem to be occurring apart from any outside pressure; rather, they are changes that educators within each subject matter area see as valuable or necessary improvements.[4]

The mathematics community has been active in this area for some time, beginning with the standards developed by the National Council of Teachers of Mathematics (NCTM) (1989). A recent NCTM publication, *Connecting Mathematics Across the Curriculum* (House & Coxford, 1995), promotes and illustrates the connections and uses of mathematics within mathematics itself; between mathematics and other disciplines; and in the life, culture, and occupational experiences of adult communities. Mathematics must be taught not as an isolated body of knowledge, but in contexts that are meaningful and relevant to learners. However, what counts as a "meaningful" context is unclear.

Any proposals to redefine a school "subject" find that a subject is defined by history, curriculum, tests, texts, and teachers. Teachers, as subject matter specialists, play a significant role in defining what gets taught, how it gets taught, and to whom (Little, 1992). Similarly, the "content" or disciplinary knowledge and skills of various occupations is defined by communities of practitioners, complete with the field's historical precedents and current working context. Any attempts to draw lines between the two face substantial challenges.

Previous attempts to identify math skills at work in order to create standards for school curricula illustrate the dilemmas. In the early 1980s, for example, several studies were carried out in England and Wales to identify the math skills and competencies needed for employment. The intent was to define mathematics requirements for students who leave school for employment at age 16 (Cockcroft, 1982). Several studies found wide discrepancies in employees' reports of mathematics skills used on the job, which resulted in underestimates of their actual skill use (Harris, 1991a).[5] Most of the hairdressers in the study, for example, denied that they used ratio and proportion when asked about mathematical skills, but when asked a practical question about mixing things, they would describe the need to mix correct proportions. Harris interprets her findings as an illustration of the differences between the origin, uses, and techniques of mathematics at school and work. Without some detailed examination of the survey data and actual work situations, these discrepancies would not have been identified. Yet survey data remain a predominate way to identify

[4] The trend toward academic and vocational curricular integration pertains primarily to middle schools (grades 6-8) and secondary schools. The elementary school curriculum has typically been more integrated between subject areas as all subjects are taught by the same teacher and as differentiation is relegated to higher grade levels (either middle, junior high, or high school, depending on the school district).

[5] For other discussions of discrepancies in identifying skills from different theoretical perspectives, see Berryman (1993), Lave (1988), Stasz (1995), and Stasz et al. (1996).

skills at work within the positivist framework and are influential in defining school subject matter content.[6]

## *New Pedagogy: The Value of Situated Learning*

The apparent discontinuities between formal knowledge (school learning) and practical knowledge (out-of-school learning) as well as research on how people learn and develop expertise has motivated new interest in experiential, or applied or contextualized learning (see Berryman & Bailey, 1992; Brown, Collins, & Duguid, 1989; Collins, Brown, & Newman, 1989; Raizen, 1989; Resnick, 1991). Research suggests that it is no longer sufficient to teach knowledge and procedures in the didactic manner that often characterizes school learning. Rather, instruction must also focus on the conditions of application of the knowledge and skills being learned. Further, the most effective learning takes place through situated activity, "using the physical environment and the tools it provides, the co-operative construction of knowledge among the group of workers (or students) doing a common task, and the culture of the specific work community" (Raizen, 1989, p. 86).

Although the empirical case for learning academics through applied or contextualized approaches is still being made, the calls for teaching academics and other skills in a more applied manner are now commonplace. Federal legislation (e.g., 1990 Amendments to the Carl Perkins Act, School-to-Work Opportunities Act of 1994) promotes applied learning and increased opportunities for students to participate in work-based learning activities linked to school. Employers and scholars alike believe that instructional tasks derived from the workplace or everyday contexts can motivate students, enhance their understanding of fundamental academic concepts, and develop their practical knowledge.

The interest for applied or situated learning strategies in mathematics is evident in publications by House and Coxford (1995) or by other mathematics teaching reformers. For example, one recent publication, *High School Mathematics at Work: Essays and Examples for the Education of All Students* (Mathematical Sciences Education Board [MSEB] and National Research Council, 1998), compiles a set of essays that deal with such topics as connecting math in work and life, the role of standards and assessments, and curricular considerations. While this report is not intended as a consensus document, it reveals a wide array of thinking on what constitutes a relevant application. One author suggests that "a good task is one that a million or more workers in the U.S. economy are being paid to solve" (Packer, 1998, p. 69). Another suggests that math tasks should have several

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[6] Several federally funded efforts to define industry skill standards rely entirely on survey data (Bailey & Merritt, 1995).

characteristics: they must require time, allow multiple solution paths, be open-ended, permit revision and extension, and develop basic skills (Kahle, 1998). Still others caution against creating "contrived" exercises (Parnell, 1998) or exercises that look applied on the surface but can be accomplished with little understanding of the underlying mathematics (Taylor, 1998). Solving mathematics problems from some workplace contexts may require more contextual knowledge than is reasonable when the goal is to learn mathematics; solving others may require more mathematics knowledge than is reasonable in high school.[7]

In short, while few question the value of applied learning, the importing of out-of-school examples into the school-based learning context is fraught with conceptual and practical problems that await further research and development.

## *The Perceived Value of Academic Skills*

Educational institutions value academic performance. General education programs primarily define skills as a set of academic competencies, which form the mainstay of the school curriculum. First and foremost, schools are responsible for teaching the basics: reading, writing, mathematics, science, and social studies. Students' grades reflect some level of skill attainments in the subject, verbal and mathematics skills, as measured on standardized tests, are the major determinant of college enrollment. As mentioned earlier, the trend since 1983 is to increase academic coursetaking requirements en route to high school graduation (Jennings, 1996).

For their part, employers seem less concerned about academic performance. In the last decade, employers and industry groups have been instrumental in redefining skills to meet the technological, managerial, and competitive demands of the workplace, as seen in the SCANS report and industry-based standard setting efforts.

Perhaps most telling are the results of a 1994 national survey which asked employers to rank a number of characteristics or attributes as critical to their hiring decisions (NCEQW, 1995). The results show that employers tend to downplay school-based factors when making these decisions. These school factors—years of schooling, grades, school reputation, and teacher recommendation—are primarily indicators of academic skills. Rather, decisions are based on an applicant's attitude and communication skills, determined through interviews, applications, and previous employers'

[7] Similar discussions about applied learning are being held among science educators (e.g., Layton, 1991; Vickers, 1998) and technology educators (e.g., Raizen, Sellwood, Todd, & Vickers, 1995).

recommendations (see Table 2.1).[8] These characteristics are indicative of worker attitudes and perhaps work competencies, not academics.

**Table 2.1.** Recruitment

| *Applicant Characteristics* | *Rank* |
|---|---|
| Applicant's attitude | 4.6 |
| Applicant's communication skills | 4.2 |
| Previous work experience | 4.0 |
| Recommendations from current employees | 3.4 |
| Previous employer recommendation | 3.4 |
| Industry-based credentials (certifying applicant's skills) | 3.2 |
| Years of completed schooling | 2.9 |
| Score on tests administered as part of the interview | 2.5 |
| Academic performance (grades) | 2.5 |
| Experience or reputation of applicant's school | 2.4 |
| Teacher recommendations | 2.1 |

**Note:** Relative ranking of factors in making hiring decisions (1 = not important or considered; 5 = very important)
**Source:** NCEQW (1995)[9]

A second administration of the survey in 1997[10] yielded essentially the same findings, suggesting that this disconnection between the education and employer communities persists over time. The similarity is especially striking given the different economic conditions of 1997 as compared to 1994. During the relatively loose labor market of the early 1990s and the substantially tighter labor market of the end of the decade, employers continue to say that they minimize the importance of schooling factors when hiring youth (Shapiro & Goertz, 1998).

The literature suggests that educators and employers may place different value on academic skills. These values affect curriculum decisionmaking in schools, and they affect employers' views about schooling (Stevenson, 1996).

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[8] The telephone survey in August and September 1994 was administered to more than 4,000 private manufacturing and non-manufacturing establishments, oversampling establishments in the manufacturing sector and those with over 100 employees. It included fields where credentials are important such as health services, construction, finance, and insurance.

[9] The results are from Question 57: When you consider hiring a new, nonsupervisory, or production worker (front-line worker), how important are the following in your decision to hire?

[10] The second administration of National Employer Survey (NES) added new questions to gauge the links between school and work and oversampled in five states where standards-based reforms included more rigorous academics.

## *Summary*

This review highlights some conflicting theoretical perspectives about skills that affect the definition and measurement of academic skills and the interpretation of research findings for educational practice. A positivist view conceives of skills as unitary, measurable traits that individuals possess and holds strong assumptions about skill transfer. The situated perspective sees skill requirements and use as part of a larger context; skill transfer is rare. These different approaches often present conflicting evidence about the perceived value of academic skills by different groups and the importance of formal knowledge for work performance. These different perspectives also bear on current ideas about what and how to teach, although the positivists are less concerned about such matters.

The debate over new skills has broad implications for schooling. New conceptions of skills expand the repertoire of basic skills that schools should teach in order to incorporate generic skills and work competencies such as problem solving, teamwork, and systems understanding. These conceptions implicitly support a multivariate view of skills by stressing that academic knowledge and skills are not enough. In the SCANS framework, for example, students should develop workplace competencies, and they should know how to apply knowledge to solve problems.

In the next two chapters, we present two new analyses which adopt a multivariate view. Chapter 3 presents evidence for academic skills at work in a study of technical workers from the situated perspective. Chapter 4 examines academic and non-academic skills in labor market performance. This analysis departs from previous studies of this type in that it adopts the multivariate perspective of skills.

CHAPTER 3

# Academic Skills at Work: Evidence from a Study of Technical Workers

This chapter draws on our previous research on workplace skills in seven technical occupations to examine academic skills at work. That study, reported in Stasz et al. (1996), aimed to improve our understanding of skills as they are manifested in technical work, both by extending the theoretical conception of skill and by providing empirical evidence of skills in practice. The 1996 study focused on "generic" skills—problem solving, teamwork, communication—and work-related dispositions but gathered information about the application of academic skills as well. We carried out additional analysis on data obtained in the original study to understand the level of academic skills required in these jobs and the contexts within which those skills are applied.

We take a situative approach to view skills at work. This approach assumes that skills must be considered from the perspective of individuals in the working community and in the context of their jobs, communities of practice[11], and work settings. Workplaces are complex, dynamic social systems that defy simplistic categorization of skills and straightforward matching of skill requirements to jobs; therefore, it is important to understand academic skills within varied work contexts.

We originally intended to emphasize mathematics and science in this analysis, as we examined English/communication skills in the first study. As the analysis proceeded, however, two issues became apparent that suggested an alteration to the initial plan: (1) the manner in which academic skills and knowledge are referred to in work practice and (2) the relationship of these skills to technology. Although mathematics knowledge is referred to with familiar labels such as algebra or trigonometry, discussion of science knowledge and skills shows greater specialization (e.g., materials science, and knowledge of medications and medical conditions) and often emphasizes interdisciplinary connections (e.g., notions of systems or relationships between areas such as electronics and electricity). In addition, use of academic skills is often firmly tied to technology applications. In order to capture these characteristics of academic skills, the analysis

[11] Within a social setting, work is often situated in communities of practice that share a preferred way of doing a task, establish standards for performances, and shape a newcomer's introduction to the working group (Lave & Wenger, 1991).

considers "science" in that broader sense and also explores relationships between academics and technology.

The next section briefly reviews the methods and sample from the previous study to provide a frame of reference for the analysis.[12] The results of the analysis and implications for educators are presented as well.

## *Study Objectives and Approach*

The study sample included sites in four firms in the Los Angeles area that represent diverse business areas: (1) a transportation agency (TA), (2) a traffic management agency (TM), (3) a microprocessor manufacturer (MPM), and (4) a health care agency (HA). The sizes of the firms, in terms of personnel, range from 26 people to tens of thousands. Two firms, TM and TA, are public agencies, while the other two are private. Three have service functions, while one—MPM—is a product manufacturer. They also serve markets of varying scale, from local (TM), to regional (TA), national (HA), and international (MPM). At the time of the study (1993-1996), most of these sites were feeling the pinch of austerity. Almost all of the workers we observed were facing rapid changes in technology and in the way their work was done. In addition, three firms had begun using new management practices such as total quality management (TQM), continuous quality improvement (CQI), or organizational learning to guide restructuring of many aspects of their operations.

At these four work sites, we studied seven service and manufacturing jobs:

- Construction inspectors and survey inspectors at the transportation agency
- Traffic signal technicians working in the traffic management agency
- Test cell associates and equipment technicians in the microprocessor manufacturing firm
- Home health aides and licensed vocational nurses (LVNs) in the health care agency

We chose technical jobs in the sub-baccalaureate labor force—the labor market for those with less than a baccalaureate degree but at least a high school diploma—for several reasons. The sub-baccalaureate labor force constitutes about three-fifths of the labor market, it has been growing steadily in the last decade, and it is poorly understood with respect to the relationship between formal schooling and subsequent employment

[12] For further details on study approach and methods, see the full study report in Stasz et al. (1996).

(Grubb, Dickinson, Giordano, & Kaplan, 1992). The focus is on technical jobs, rather than entry-level jobs associated with a service economy, because technical jobs are growing and because they are more likely to be affected by the links of workforce changes that help create new skill demands (Barley, 1995).

Over several days, we observed workers' everyday activities and interviewed them to obtain information about their backgrounds (e.g., previous education and training experiences) and current job and work experiences. We also conducted interviews with senior managers, staff, line managers, and human resource personnel in order to obtain information regarding each firm and its hiring and training policies and on their views of the skills needed in these jobs.

The original study focused on three skill areas—(1) problem solving, (2) communication, and (3) teamwork—as well as work-related dispositions. These have generally been perceived to be required in the workforce (cf. Berryman & Bailey, 1992; SCANS, 1991, 1992) and are of particular interest to employers (cf. NCEQW, 1995). The study asked several questions concerning generic skills:

- Are generic skills and work-related dispositions evident in performing these jobs?
- How do workers conceive of them?
- How do these skills and dispositions vary across jobs and work contexts?
- How do firms view skill requirements?
- How do these views affect human resource policies such as recruitment, hiring, and training?

The new analysis reported here follows procedures employed for the initial study. Interviews and fieldnotes were entered into an online database for handling text data. Fieldworkers coded these data with index categories that corresponded to the questions of interest to the study such as the skills used on the job, work tasks, and social relations. The coding scheme was developed iteratively, building on the initial domains by adding categories that emerged at different sites. Once our preliminary analysis was completed, we returned to each work site to debrief study participants on our interpretations of the results and study findings. The debriefing provided a validity check on our findings and gave study participants the opportunity to discuss implications for their own work site.

Several questions were explored in this analysis:

- What academic skills are evident in these jobs? How do they fit into the broader work context?
- Are these academic skills central to the job or only required for certain work tasks or technology applications?

- How does the community of practice regard academic skills? How does academic knowledge and skill relate to work practice in a broader sense? Have skill requirements changed within a profession in which changes in technology or other factors have taken place?

Our analysis confirms that work context matters in the consideration of skills. We found that academic skills are essential to the performance of work in these jobs and settings, although they vary according to job, community of practice, and work setting. They also vary by level, with some jobs requiring high-level mathematics, for example. To fully appreciate the contextual richness of these jobs, interested readers may want to read the scenarios provided in Appendix I, which are based on data gathered from observations, interviews, and documents collected at the study sites.

## *Mathematics at Work*

In this section, we consider how communities of practice regard mathematical knowledge and how that knowledge relates to practice in a broader sense—for example, how math requirements have changed within a profession in which changes in technology or other factors have taken place. We consider the level of mathematics required in work tasks, from simple arithmetic to the use of high-level mathematics such as trigonometry. We also consider the centrality of mathematics to work: Is math essential for doing one's job or is it required only for certain tasks or technology applications? Using specific examples to illustrate these aspects of math at work, we show that mathematics in practice differs considerably across these jobs.[13]

Overall, although all the frontline workers in our study used math on the job, mathematics is clearly more central to some jobs than others (see Table 3.1). In the traffic management business, electronics is the core discipline, and mathematics is a basic tool of electronics. As one manager told us, "traffic signal management is all about electronics, so techs need math to understand the electronics." When traffic signal technicians discuss math, it is in reference to electronic examples or problems.

The test cell and equipment technicians at the semiconductor plant also require basic electronics knowledge for their jobs. This knowledge is important for operating sophisticated equipment, but it is not viewed as a defining characteristic of their work. For these technicians, although they may use mathematics in their job, the essential aspect of their work is keeping up with technological equipment which may have a floor life as short as six months.

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[13] For confidentiality reasons, we use pseudonyms for proper names appearing in examples. We identify sources of information with titles or site locations.

Mathematics is also essential to survey inspection but in an entirely different context. Survey inspectors, particularly the party chief who heads a survey crew, must make complicated calculations and measurements. A large part of the chief's job is calculating the exact horizontal and vertical placements from objects in the field from two-dimensional plan specifications. Depending on the situation, these calculations can be straightforward or very complex, as illustrated in some examples that follow. Survey inspectors' mathematical expertise is also recognized by others; the party chief reports

**Table 3.1**
**Mathematics Skills and Tasks**

| | **Skills** | **Task Examples** |
|---|---|---|
| Construction Inspector | • **Algebra**<br>• Geometry<br>• Trigonometry | • Verifies calculations on blueprint/specifications<br>• Calculates pressure limits for elevator liner<br>• Measures and records corrections to specifications |
| Survey Inspector | • **Trigonometry**<br>• Algebra<br>• Geometry<br>• Statistics | • Measures spiral track and compares with design specifications |
| Traffic Signal Technician | • **Any math related to electronics (e.g., algebra)**<br>• Trigonometry<br>• Calculus | • Computes resistance to determine which type of wire to install<br>• Sets controller timing at traffic intersections<br>• Reads and understands sine waves in oscilloscope |
| Test-Cell Technician | • **Basic math**<br>• Statistics | • Calculates percentage (RPM) to determine how long a test should run |
| Equipment Technician | • **Any math related to basic electronics**<br>• **Algebra**<br>• Statistics | • Plots and reads a pressure graph<br>• Reads and understands output from statistical analysis (e.g., standard deviations) |
| Home Health Aide | • **Basic math** | • Uses calculator to figure out mileage<br>• Completes records |
| Licensed Vocational Nurse | • **Basic math** | • Calculates flow of fluid in intravenous pump<br>• Calculates percentages to check doses of medication |

**Note:** Skills in **bold** are used more often; that is, they are more central to the work.

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that contractors or other craftsmen at work sites depend on surveyors to check or make mathematical calculations. The following excerpt from the fieldnotes illustrates this interdependency:

> A civil engineer called on the radio to ask a question about a staircase at a particular station. The top of a staircase was going to fall one inch short of the platform, and the engineer needed help in understanding why, so he could craft a solution. Over the radio, without performing calculations on paper, the chief was able to understand the problem being described. He formulated a hypothesis, and made some simple calculations to confirm it. He told the observer that he recognized the problem from the description, constructed a picture of it "in his head," and used calculations to confirm his solution. [TA fieldnotes]

While mathematics is also important in the other jobs we studied, it is not a defining factor of those occupations; rather, mathematics is necessary because of its connection to certain tasks or technology.

### Variations in Level of Mathematics

The level of mathematics needed in the jobs we cite in this chapter varies considerably. In this section, we provide several examples, beginning with jobs and tasks requiring fairly basic to more advanced mathematics skills (see Table 3.1). We define "basic" math as calculation using addition, multiplication, subtraction, or division. In these examples, it is also apparent that mathematics is firmly linked to task and technology.

#### *Basic Mathematics*

The home health aides and LVNs need only basic mathematics skills. Each is licensed to carry out particular tasks, with LVN work requiring more mathematics knowledge. Home health aides and their supervisors report little need for math on the job; at most, they use a calculator to figure out their reimbursable mileage or do simple calculations for recordkeeping. LVNs, however, have responsibilities for patients' medications, take their vital signs, and work with various kinds of equipment. When asked about the technical skills required in her job, an LVN gave the following example:

> You have some [patients] that are being monitored through a pump. You have to know how to calculate your rate per minute, the volume that the machine is going to deliver, and how many cc's per minute. So you have to know how to set that up. If the doctor says, well I want the patient to have 24, well say 2,000 cc's of fluid over a period of six hours, you would have to know how to set that up. And most patients, if that patient is having that kind of a drip, you would have to know how to set up your equipment.

This example shows how mathematics is embedded in setting up particular equipment, in this case a pump apparatus that dispenses fluids intravenously. The LVN considers this to be a technical task and, although it requires mathematical calculation on her part, she does not describe the mathematics concepts or operations involved. Rather, the explanation is tied to the delivery of fluids through the pump, as prescribed by the doctor.

The mathematics "embedded in the task" is also tied to the social context of the LVN's work. She participates as a member of a managed care team, in which authority and tasks are specified for each job. She communicates with doctors or other health professionals and carries out their prescriptions for patient care when she visits a patient in the home. In the following examples, she discusses mathematics again, also in the context of describing technical skills:

> Technical is doing your diabetic teaching. You have to know as far as your units, if the doctor says to give the patients 20 units of NPH, you have to know what—how is he using, what are his units? You have to know units in comparison to cc's or milligrams or what have you.

This example shows that doctors may define a "unit" in different ways. Part of her task, then, is first understanding how a particular doctor defines a unit, as this will affect the calculation she needs to make.

When asked whether math skills were required for their jobs, most respondents in the HA discussed math in the context of specific tasks:

> It's helpful. Matter-of-fact, you really should have a lot because you know, you're constantly dealing with your drugs, your patient's medications. And you have to be able to recognize the milligrams, what have you. Or if you're doing your diabetic teaching, you have to know as far as your units, as far as your insulin, so you need quite a bit of math skills. [LVN]

These examples illustrate that within this community of practice, mathematics is embedded in technical aspects of the job. Furthermore, the meaning of a term directly related to doing the mathematics can be highly specific. For example, "unit" may be defined differently by different doctors. In this case, understanding the meaning is essential to properly carrying out the task.

*Math and Electronics*

Several jobs involve electronics and require enough mathematics to deal with particular tasks or technology. In the traffic management world, technicians, supervisors, and managers universally agree that technicians need basic mathematics skills and algebra. In their view, any mathematics associated with electronics is considered "basic." Trigonometry, geometry, and calculus were less frequently mentioned but can also be required from time-to-time.

Traffic signal technicians use mathematics to repair and maintain equipment both in the shop and out in the field:

> It's not just in the shop that you're doing this [math] either. If you were working in an intersection to where you have a service point, then you have your cabinet, and it needs to get the power. You know you have a certain type of wire that has a certain amount of ohmage or amount of resistance per foot. Does it make sense that you have 120 volts here and 100 volts here? What's the problem? Why the loss? Well, I've got 400 feet times how many ohms per foot. That's within reason. OK, so I've got to pull a different type of wire there. You can't just sit there and say it won't work. You have to do some figuring. [TM manager]

Algebra comes in handy for technicians working with test equipment:

> You need algebra because you have to do a lot of plotting, a lot of percentages and stuff like that, [and] a lot of decimal numbers. All the pressures are negative pressures, so you've got to know a little about a timeline and stuff. I'd say, you don't need calculus, but you need to know how to plot, how to read a graph. [TS technician]

Use of different types of technologies also figures heavily into mathematics requirements on the job. Traffic signal technicians, for example, work with oscilloscopes, which requires some understanding of trigonometry:

> Trigonometry is really tied with electrical theory and how power is calculated. That building block is essential . . . because you need to understand vectors. Our specifications call for a certain part of the sign wave—which is the electrical symbol for opening a current—where the different components will flow, or will turn on and off. They have to be able to read what a sign wave looks like and what the degree marks are. Where do you get that exactly in a mathematical background? It's not just basic math. [TM manager]

Depending on the technology available in a particular traffic management department, traffic signal technicians may need to set controller timing at traffic intersections. One technician described the task as follows:

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> We've each been given a calculator watch because the way signal systems were done previously was by percents. If you had a 90 second cycle and that equals 100%, you need to know if you want to make what they call a 45-55% split—you want to split the 90 seconds. You want to give 45% of it to one direction and 55% to the other. Then you need general math skills and a calculator.

In jurisdictions with newer technologies, however, signal control may occur from a centralized control room, which sends signals to microprocessor-based controllers located at street intersections (see description of this system in Appendix I). In this case, technicians won't use math to set timing, but need to "know how the monitors really work—how the programming actually relates to what actually happens in the field." As discussed further below, the shift from electromechanical to digital technology in traffic management has had a widespread impact on skill needs.

*Beyond Algebra*

In comparison to other jobs, survey inspectors' work requires the most advanced mathematics, including algebra, geometry, and trigonometry. As the "chain man" on the survey crew described math skills, "Trigonometry is what we do." To become qualified even as an apprentice, surveyors must take an examination that tests the applicant's ability in both trigonometry and algebra. The crew chief in our study also occasionally uses least-square regression and other statistical techniques that go beyond the normal mathematics required for surveying. He does this both to keep his skills up and as a means of independently testing some of his earlier calculations.

The following excerpt from TA fieldnotes provides a typical example of the mathematics involved in survey work:

> There's a lot of calculating to do in this job, most of which seems to be the responsibility of the chief. He compares copies of design drawings with his charts of "control points," which he has previously checked for height, azimuth (the horizontal distance from a fixed control point), and elevation, checking and rechecking correct survey points to ensure that the object being placed will be correct. The surveyor must calculate "northings" and "eastings" (placement in the vertical and horizontal dimensions of a plane) and the elevation (height) of the object. This is not just rote calculation.

The transportation work observed in this study was somewhat unique as the geometry of the rails and tracks introduces specific construction and inspection challenges such as spiral curves. A spiral curve is a parabola: one track is higher than the other to accommodate faster train speeds at a curve. While calculating spirals is a challenge to even a skilled surveyor, it is also a fairly rare occurrence; the supervisor estimates that a surveyor will only run into such problems on one percent of jobs. Spirals also introduce new terminology in the surveyors' lexicon that is only used in rail work.

The chief described the procedure for calculating a "very substantial" spiral. The crew first establishes the horizontal, then measures the spiral off the horizontal to ensure that the relative heights of the rail are correct at each point. Spirals are similar to curves, but whereas curves have a constant radius and a fixed center point, spirals do not. Thus, the crew is unable to use in their calculations the relatively simple formulas for circles. More complex calculation is required.

Surveyors also feel that future technologies such as the global positioning system (GPS) may significantly impact their work, although the underlying mathematics knowledge remains fairly constant. In this field, as in others, the worker needs to understand the underlying concepts behind the technology application and how that relates to the work setting.

## *Science and Disciplinary Knowledge*

Our analysis of mathematics at work shows how math requirements differ among technical jobs and run the gamut from basic skills (e.g., add numbers, calculate percentages) to complex applications of trigonometry (e.g., calculate spiral curves). Mathematics can be completely integrated within a discipline, as is the case with electronics, and therefore defined as part of the job. Or mathematics can be essential, but used infrequently, as is the case with the health care workers. With a few exceptions, most of the study participants use familiar labels to speak about mathematics (e.g., algebra, trigonometry). They also discuss mathematics in relation to operating specific equipment.

When we turn to science, the picture becomes quite murky. The "academic" science evident in these jobs is quite varied and often specialized and does not map well to the subject areas defined in typical high school curricula. In the context of technical work, it is more accurate to discuss science content as disciplinary knowledge which may draw on various sciences. Science, or more accurately the application of science principles, is firmly tied to technology or tool use. For that reason, our discussion emphasizes the science-technology connections and the specialization of knowledge that is needed to work with technical systems (see Table 3.2). It is often the technical requirements or work processes that create the demand for different types of scientific knowledge and understanding.

## Table 3.2
## Science and Technology Applications

| | Science/Disciplinary Knowledge | Technology/ Tool Examples |
|---|---|---|
| Construction Inspector | • Various specialties (e.g., concrete, electrical, metallurgy, communications, mining, mechanical)<br>• Hazardous materials | • Basic tools (e.g., tape, square, level, calculator, safety equipment) |
| Survey Inspector | • Laser<br>• Electronics<br>• Hazardous materials | • Calculator<br>• Global positioning system<br>• Electronic distance measurement (EDM) machine<br>• Back site<br>• Linear rod<br>• "Homemade" tools (e.g., level) |
| Traffic Signal Technician | • Electricity<br>• Electronics<br>• Hazardous materials | • Oscilloscope (digital and analog)<br>• Digital millimeter<br>• Basic tools (e.g., soldering iron, pliers, socket wrench, safety equipment)<br>• Microwave communication<br>• Portable computer |
| Test-Cell Technician | • Electronics | • Centrifuge<br>• Oscilloscope<br>• Microscope<br>• Specialized microchip testing equipment |
| Equipment Technician | • Hazardous materials<br>• Electronics<br>• Pneumatic<br>• High-vacuum equipment<br>• Basic chemistry<br>• Electro-mechanical aptitude | • Photo lithography machine<br>• Acid processing machine<br>• Microscope<br>• Specialized manufacturing equipment (e.g., implanter, sputter, diffuser) |
| Home Health Aide | • Basic assessment (e.g., skin care)<br>• CPR<br>• Vital signs | • Blood pressure cuff, thermometer, stethoscope<br>• Hoyer lift<br>• Humidifier<br>• Suction machine<br>• Ventilator |
| Licensed Vocational Nurse | • Basic assessment medications<br>• Wound care<br>• CPR | • Suction machine<br>• Intravenous (IV) pump<br>• Blood draw<br>• Catheter<br>• Portable doppler<br>• Ventilator |

*Electronics*

Electronics is one discipline which applies to several jobs in our study: traffic signal technicians at TA and test-cell and equipment technicians at the MPM. As mentioned earlier, electronics is central to traffic management work and the way technicians and others within a community of practice define what they do. The dominance of electronics and the increasing demand for workers with more and more sophisticated electronics background is directly related to a major shift in signal technology. One manager described this change as follows:

> Basically, the original traffic signals are all electromechanical. In the past, a person with a good mechanical ability and a good reading comprehension could come in, and after four or five or six months of on-the-job working with other technicians and other electricians could pick up the repair and the maintenance of traffic equipment. Over the last 20 years, the mechanical has gone out and digital and computers have come in. Now he [the technician] still needs mechanical ability to disassemble and tear apart equipment, but he has to have a high technical ability to understand computers—software, hardware, programming—and how to troubleshoot all the sophisticated electronics and computer equipment. You have to have the technical basic building blocks. You need the math, you need the physics, you need the electronics. [TM manager]

The old electromechanical controllers used alternating current similar to what is found in a house. The flow of current can be easily tested with a test light or a volt meter of simple design. Now the controllers can be fine-tuned to tenths or even hundredths of a volt, which makes them harder to maintain and repair: "Any kind of grit or any kind of a solder splash will cause problems." The technicians need to be familiar with different kinds of semiconductors. According to a supervisor, "They have to have the expertise to know, not so much how to construct that [a semiconductor] but they need to know the theory behind semiconductors, behind erasable program readable memories—that type of stuff. That's where the computer technology comes in."

Managers and supervisors also feel that it is easier to train a digital or computer technician to become a traffic technician than it is to train an electrician how to work effectively in an electronic world.

At the MPM, the test and equipment technicians operate and troubleshoot sophisticated electronic equipment. To do so, they need to understand what each machine does and how it operates, and the underlying concepts and processes that come into play. During any operation, they may use mathematics, science, and computing skills such as programming. An equipment technician describes the elements of his job:

. . . you have to know a little bit of everything to do it. . . . It's about 80-90% mechanical, 5% electronics, plus chemistry and other science. When we look for new people [to hire in the job], we look for people with the ability to fix cars.

Another technician described the work similarly: "80% of my job is mechanical, 20% electrical." Electronics knowledge is important, but less so than mechanical aptitude and understanding of the electronic equipment. As we will discuss further, the work for these technicians is really defined by the technology they use.

*Medicine and Patient Care*

The home care providers are members of a managed-care team in which knowledge and authority are linked to special certification and distributed among the team members. Knowledge is distributed among the various specialists—aides, doctors, nurses, speech therapists, pharmacists, and so on. Levels of authority in a team are related to certifications. Thus, LVNs and home health aides are not permitted to perform several tasks in the nurses' domain, including initial patient assessment, plan of care, and decisionmaking as to whether or not a patient needs to continue with care. Because of liability issues associated with health care and certification policies, the authority structure is formalized through work rules and procedures. Although both aides and LVNs need medical knowledge, what they need to know, and in what depth, depends on the tasks and procedures that they are permitted to carry out. LVNs have more responsibilities than aides; therefore, their knowledge of medicine and patient care is more extensive.

Aides need to know how to take blood pressure and temperatures, but they do not assess other vital signs (in this particular health agency). LVNs, however, take vital signs, draw blood, teach patient care to patients and their home caregivers, perform CPR, and treat wounds. Because they gather information about the patient's condition to report back to the case manager (usually a registered nurse), they need basic assessment skills as well as some understanding of physiology related to particular illnesses (e.g., diabetes). The following excerpt from the fieldnotes describes an instance where a home care worker gathers information and advises a caregiver:

The wife said that sometimes her husband experiences tremors, but the bottle on his Ventolin [his asthma medication] lists tremors as a side effect. The aide asks about his dosage and if the tremors occur soon after he's taken the medicine. The wife's response suggested that the Ventolin was not causing the tremors, and the aide made a note of the problem. She asked the wife whether she had told the doctor about these side effects. The wife responded that she had not. The aide advised her to discuss this with the neurologist at their next appointment. [HA fieldnotes]

Since LVNs have broader responsibilities, they may need extensive knowledge about medications. LVNs may review lab reports, for example, and pass them on to the nurse. Since the nurse makes the initial assessment, and the LVNs do the follow-up, the LVNs must track reports to know when or if the condition worsens and whether the nurse needs to intervene. They need to know about wounds and wound care, since they will often need to change a patient's dressings.

When asked about basic assessment skills needed by an aide, an HA supervisor gave the following example:

> Things like basic skin care. They need to be able to say, this area is reddened; reddened skin means we're going to have a problem here and I need to tell my supervisor about it. And also knowing, for example, this patient was conversing with me yesterday and they're terribly confused today. That's a difference. I need to report that. Most of the people we see in home care are elderly people, so having an idea of what it means to be old and all the psychological changes that go with that are important because the aides have to deal with that.

Home care supervisors emphasize that aides and LVNs needed more skills and knowledge than similarly credentialed staff who worked in health facilities. These individuals are "in the home alone, so they have to pick up the information, and they have to know what information to pick up and report back." According to one supervisor, the medical knowledge or technical skills alone are necessary, but not sufficient: "It's the ability to problem solve and to assess the situation yourself without input from anybody else. To look at pieces of information and know what direction to go."

Knowledge develops with experience, whether it concerns reading and assessing medical symptoms or diagnosing a problem with a traffic signal controller. The following HA fieldnote excerpt about an experienced LVN provides one example:

> I asked later how she can tell about a patient's condition since neither of the last two were able to speak. She said she talks to the caretakers and "just knows." She has seen the patients enough times to know what they should look like and how they will respond to her presence and touch. She has many physical indications, in this case the catheter. She can check it to see how well they are draining and what color the fluid is. She explained that today, although the caretaker said she was giving the patient a more diverse diet, the woman's urine was a bit

cloudy, so the caretaker could not have been telling the truth. The nurse said she was going to report that to her supervisor.

*Materials Science*

Some technical work requires special knowledge of materials. Traffic signal technicians, for example, need to know about the strength and flexibility of different types of wire: "You have to know if you flex this copper, it's gonna break." Construction inspectors have specialized knowledge (e.g., in concrete work, electrical work) that defines their individual inspection tasks; some are specialized in several disciplines. Some of the knowledge requirements are fairly standard; inspectors describe knowledge of soils and concrete testing as "basic stuff." Each inspector makes rounds at the construction site (in this case a subway) to inspect areas specifically related to his discipline. As he makes his rounds, he is also on the alert for activity in the other disciplines. When he spots a problem or knows that the work has reached an inspection point, he contacts the appropriate inspector by radio. Thus, inspectors are knowledgeable about the materials related to their own discipline and often learn enough about other areas to increase the efficiency and quality of the inspectors' collective work on a job:

> The cement truck arrived to begin pouring the wall in the ancillary area. Alex radioed Mike that the carpenters are close to finishing. On hand is a technician from an independent lab. The technician takes samples that will be used to take the cement through a 28-day stress test. Mike and the technician checked the test cylinders. These cylinders sit outside in the area of the site and are sensitive to temperature and moisture changes. Since cement is a mix of cement, aggregate, and water, Mike explains that they want to make sure that the mix can withstand climate changes while curing. It is his job to ensure that concrete inspection is accomplished according to specifications. He said they often use an independent lab for stress testing when there is a "major pour." [TA fieldnotes]

Inspectors need to be able to look at the construction to see that the "right" material, as specified on the drawings, is being used and that it is coated properly. Concrete technologies are becoming more chemically oriented, so inspectors need to keep up with changes in materials. In the following excerpt from the TA fieldnotes, inspectors present problems at a weekly meeting to solicit advice, thereby taking advantage of their collective knowledge and experience:

> At a meeting of lead inspectors, inspector #2 continued by asking for advice on a cement problem: The cement was mixed with too much

water and did not pass the compactor test. He said they "just missed the envelope." Other inspectors asked several technical questions about the cross aggregate base. Inspector #3 offered that "those guys [referring to the state transportation agency] are used to just adding water and let it [the cement] sit for a day, but you don't have that luxury." Others agreed that this was the problem. The gravel-voiced "old timer" asked, "What's the poundage? Most of these guys are still using specs [specifications] out of the horse and buggy days. The sharper crowd advocate using vibrating rollers." This brought general agreement that the thing to do is to have vibrating rollers on the site to use in the next street restoration. Other advice: Call back east to check on the feasibility of using "reclaim"; have the soil guy take a moisture test ahead of time; [and] find out the bond and its screening capacity. This was an open and professional discussion without grandstanding or accusation.

## *Technology and Systems Understanding*

As can be seen in Table 3.2, the array of technology at the work sites can be quite extensive. While technology certainly affects all the jobs we studied, it really defines the work of test-cell and equipment technicians. According to technicians, the job requires a "man over machine" attitude, where the technician is not overwhelmed by the technology but feels in charge (Stasz et al., 1996).

One reason they need a high level of mechanical skill is that the equipment changes frequently, sometimes having an operating life of only six months. This particular company is also known for inventing cutting-edge equipment for semiconductor manufacturing.

In addition to mechanical skills or aptitude in "how things work," technicians need to understand enough of what a machine does to be able to predict how it will behave if some adjustment is made. As one test technician describes, this brings different science knowledge into play:

> So you have to know how things are going to work and to see if it's broken—see where on the shafts and stuff like that. You need to know about implanters, sputters, and all your acid equipment. You can't just go in there with a wrench because you've got pressure. If you open something, you don't know if it's going to shoot out a little or just gonna keep on shooting forever. So you've got to understand a little before you can go up there and just start. I'd say probably the only machine—well, even microscopes are tough—you can't just go up there and start messing around without knowing what you're doing.

In this, as in earlier examples, we see that the technician speaks of a concept, in this case "pressure," in reference to a particular process and equipment.

These technicians and those working with traffic signals also need to understand electronic devices. While the test technician in the preceding example can see the results of adjusting his piece of machinery, technicians working with electronic devices also encounter the "black box." To troubleshoot, they must comprehend both the electronics and the computers:

> Is it a failure of the equipment or a failure of the program? So I have to be able to separate out and determine—am I looking at a program glitch or am I looking at an equipment glitch? [Traffic signal technician]

Technicians also differentiate between mechanical know-how and technical understanding:

> Most of the problems, people always think, are electronic. But a lot of your problems are just mechanical. They just don't understand how the machine is working. [Test technician]

Finally, they distinguish between theoretical understanding and hands-on or practical understanding of technology:

> There are people who have studied and can study well and can take tests well. They are very book knowledgeable, but they can't apply it practically. Some don't have book knowledge, but are more hands-on oriented. They can go and read on what needs to be done, and they are able to apply it. Or you can tell them. But they are missing the technical understanding. They may know every component inside, but they won't know what it does. Knowing it and knowing what to do with it are two different things. [Traffic signal technician]

The home health providers also confront a wide array of technology in the homes, but they do not really need to understand how it works. The critical understanding is how it operates and knowing if the equipment is malfunctioning. Aides or LVNs are not required to troubleshoot any problems but only to report them to the case manager, who will send someone else to make repairs:

> Well, they will probably be encountering special beds that have a lot of built-in features that need to be manipulated. They encounter patients on continuous oxygen therapy. We should not be depending on respiratory people to go over there to check. They should be able

to check the safety, that the humidifier is working fine, that there's enough water. They should at least be familiar with ventilator machines and be able to detect if it's working or not. They don't have to troubleshoot it, but be able to recognize that there are some signs of dysfunction. The home may have a suction machine if patients and their families are expected to do their own irrigation of cuts. A patient may have an intermittent thermalitic pressure device for his leg. LVNs should know how to use that. [HA manager]

Understanding the mechanical and theoretical aspects of the technology may also permit technicians to build more efficient tools:

Ken mentioned that at one of his previous jobs they used teflon coils to do the same thing, and it was much simpler. Rich wasn't familiar with that technology, so asked Ken to say more about it and bring him an example or drawing if he could. Ken went on to say that many parts are "overdesigned" by the vendor and have many redundant components. He and the other technicians will often strip down equipment and rebuild a more streamlined and better piece of machinery. [MPM fieldnotes]

Although employers often expect to provide job-specific training to new workers, managers and supervisors for most jobs emphasize the need for technical skills. They look for individuals who have experience with cutting-edge technologies, and they are willing to pay a premium for a skilled worker:

Technology is really affecting survey work. In the field, the instrument man now uses a sophisticated gun. This job is becoming more and more specialized as the equipment becomes more complex. Instrument men can almost guarantee themselves work by mastering the operation of the cutting-edge machines. [TA supervisor]

Hands-on experience is very important, especially with particular equipment within the semiconductor industry, e.g., scope, monitor, microscope, equipment for testing purposes. People with this background can start at a higher level. [MPM human resources director]

*Systems Understanding*

As can be seen in the work scenarios in Appendix I and the examples cited above, work in these technical occupations involves a complex set of processes, technology, and social systems. Understanding how these systems operate and interact is crucial to the work. Systems understanding can have different requirements—for example, the abstraction of underlying principles from different systems to see how they overlap or the mapping of different symbol systems. In our discussions about skill needs, respondents provided many comments about the importance of understanding systems:

> Well, first of all, traffic control is a very specialized field because it's more than just electrical engineering work or the electronic. You have to know the logics [sic]—how to work in the streets, how the traffic moves. So there are some basic principles you have to understand before you get into the traffic control business because it relates directly to the safety of people. You need a mental model of how the actions you take with the signal affect flow and basic safety issues. [TM manager]

In this example, the understanding of systems concerns relationships between signals and public safety. Similarly, in home health care, several important systems come into play: the condition of the particular patient, the expected effects between medical practice and patient well-being, and the specific rules that delineate the social organization of work among health care practitioners with differing credentials.

Construction inspection and survey inspection jobs require constant reference to and switching between two different depictions of the construction project: the two-dimensional plans and blueprints that define the legal specifications for the construction and the actual, three-dimensional built environment. Inspectors constantly navigate between the two representations. According to our observations and interviews, they consult mental models, draw pictures, or gesture to one another in problem solving or communicating about spatial relationships. Inspectors need to have sophisticated skills in reading blueprints, not only because a subway project yields a large number of complex drawings, but because the drawings change frequently as the work progresses:

> I follow the inspector on his way to the roof slab to check on the installation of sump and ejector pumps within the plumbing system. He is the mechanical expert. The plumbing system is within the "guts" of the roof slab. We climb down a shaky ladder to the work area. He checks on the installation of a plastic "frame" inside the wall. Although the entire subway will be in a plastic liner envelope, they want to add protection to all the external walls. He climbs onto the top of the wall to observe the installation, then inches along the top [on the carpenter's scaffolding] to inspect what had already been installed. Later he finds a problem with a liner that has already been installed. The contractor wants to pour the elevator casing, but the liner has not been tested for

leaks. The contractor claims the inspector did not indicate that a leak test was needed first. They return to the office to look and the drawings and specs [a note about the requested test would have been added to them] and to sort things out. [TA fieldnotes]

## *Breakdowns and Skill "Failures"*

Our study also provides information about consequences when workers lack crucial academic knowledge or understanding, as the following excerpts illustrate:

> Sometimes lack of technical skills can slow progress. For example, the expert in the group has an AA in electrical engineering and learned the job in 2-3 months. The youngest member of the group has only a high school degree. Though he did have electronics courses, he has still not learned the basics in seven months. [MPM supervisor]

In the manufacturing environment, time is money. Employers are keen to identify and hire workers who have the necessary basic skills. They expect to train individuals to operate and maintain specific equipment, and will often make production allowances during training periods. If incumbent workers lack adequate disciplinary knowledge, in this case electronics, they take longer to become productive workers and may take longer to develop expertise.

Another example comes from observations of the test-cell, in which a novice worker's conceptual understanding of the technology is different from the expert's:

> I ask the operator [a novice] what the PIND tests for. She responds that it tests for loose particles in the chip that could damage the device when it is in use. She tells me that the device shakes each chip and provides a readout indicating if there is a loose particle in the chip. I probe, asking how the machine operates. She repeats her previous response. I plan to ask Stan and Ng later, but Stan [the expert] jumps in and explains what the machine is doing: The vibration should shake any particle in the chip loose and the machine measures unexpected noise arising from the vibration of the part. [MPM fieldnotes]

Although the novice's lack of thorough understanding did not affect the work process in this case, it may have caused problems if the machine needed adjusting and the expert was not available to provide assistance. In the following examples from test-cell observations, reported in the MPM fieldnotes, experts come to the aid of coworkers who have problems with their math:

They are working on the centrifuge. The other tech is having trouble calculating how many RPMs and how long each test is supposed to run. Stan shows him the appropriate page from the process specs manual that sits right next to the machine. Stan takes out a calculator to show him an example of how the calculations are to be completed.

She has a great deal of difficulty explaining how to fill in the test, in part because she cannot figure out how to calculate percentages correctly. Eventually, Stan shows her how to calculate the figures, and asks her if she can show them how to mount different chips on the device.

## *Conclusions*

Our analysis suggests that any description of knowledge and skill must relate to several aspects of the job, including the tasks and processes the worker carries out, the technologies in place, and the social context that delineates work responsibilities and interdependencies among individuals. Also evident is the need to understand relationships among systems, both human and technical, and within a single process or technology application. Technical workers discuss the need to know both how something works and why it works that way. Our results concur with Barley's (1995) observation that technical work resembles craft work and that "most valued skills appear to be those developed in hands-on conversation with materials and techniques" (p. 15). He refers to these as "artisanal" rather than formal knowledge and skills.

The present analysis provides a rich picture of academic skills in work. Our analysis only skims the surface, however. It provides snapshots of the complex relationships between academic knowledge and work context but does not explore every aspect of work. Other important relationships are likely. Given these limitations, we draw the following conclusions about the technical work that we studied:

- Technical work incorporates a wide variety of mathematics skill levels, ranging from basic mathematics (pre-algebra) to complex trigonometry. Many workers use mathematics regularly on the job, and some, notably survey inspectors, cannot do their job without mathematics.
- Mathematics, science, and disciplinary knowledge varies with work context. In some cases, the work is dominated by a few disciplines or subject areas such as medical knowledge for home health caregivers; electronics knowledge for traffic signal, test-cell, and equipment technicians; and mathematics for surveyors. Other work may require broad disciplinary knowledge, as in construction inspection.

- Technical workers may not discuss academics in the terms typically used in school. Rather, math or science topics, even when formal terms are used, are most often described in relation to a particular work process or technology application. In these cases, it seems that technology may render knowledge opaque—hard to know about or construct apart from the technology.
- In some communities of practice, it can be important to establish the precise meaning of terms related to math or science applications because individuals within a community can define important concepts in different ways. Misunderstandings could lead to costly or even fatal errors.
- Technology may define work practice. In some jobs, answers to questions about academic skill needs will depend on the technology at hand and the expectations about new technologies that will be used in the future. Specialized mathematics and science skills may be needed, particularly for technicians who have maintenance and troubleshooting responsibilities.
- Managers' and supervisors' understanding of academic skill requirements appear consistent with frontline workers' own estimation. This finding departs from our previous study of generic skills in which employers and workers often disagreed about capabilities related to problem-solving, communication, and other "soft" skills. In that study, employers often underestimated skill use. Since academic skills are commonly measured, either by tests or other indicators (e.g., courses taken, degrees, or credentials), it may mean that employers are using such measures to assess skills, and make use of these assessments in selection, hiring, and compensation decisions.

In the next chapter, we take a look at academic skills from a positivist perspective and discuss relationships between cognitive and noncognitive skills and labor market outcomes.

CHAPTER 4

# Academic and Non-Academic Skills in Labor Market Performance

## *Introduction*

> The understanding of the role education plays in labor market success . . . was identified and championed by labor economists . . . . (Capelli, 1996)

The research of labor economists has long documented the positive relationship between formal education and earnings. Individuals with more years of schooling have higher earnings and job status, other things being equal. Within this positivist view of skills, it is generally held that schooling improves an individual's set of skills and, hence, productivity in the labor market (Becker, 1962; Mincer, 1974). Precisely how this occurs, and what kinds of aptitudes schooling enhances, is less clear. Most researchers and policymakers have focused overwhelmingly on *academic* knowledge, skill, and ability, typically measured by standardized test scores or crude curriculum indicators—the backbone of formal classroom learning in most school settings (e.g., Altonji, 1995; Murnane et al., 1995). Criticisms of U.S. public schools invariably focus on perceived poor academic attainment and the need for improvements if the country is to remain economically competitive (Finn, 1993; NCEE, 1983). Much of the school reform activity during the past decade or so has focused on raising basic academic skills (Jennings, 1996).

Recent research on the changing nature of work and the types of competencies that employers use has led to a broader conception of skills, however (Capelli, 1996; Stasz et al., 1996). As discussed in Chapter 1, various conceptions have been suggested (e.g., SCANS skills) to incorporate academics and various "generic skills and dispositions" which are thought to be particularly useful in the workplace. Along with this expanded definition of skills, the research suggests that it is not appropriate to view academic skills as isolated or separate from other skills. Rather, it is important to recognize that skills act in concert (i.e., the concept of skill is multivariate), and that skilled performance is sensitive to context.

These ideas about the characteristics of skills have not found their way into quantitative research on labor market performance. The omission of potentially important non-academic skills—problem solving, teamwork, communication, or work-related dispositions—in quantitative research occurs for several reasons. First, viewing skills as multidimensional is relatively new, and many researchers are unaware of research in the area. Second, it is often assumed that there is a strong positive correlation between academic and other skills. In other words, it is believed that achievement on a math test also indicates problem-solving ability in other settings, or that having taken numerous courses in English indicates a high level of communication skills. Whether this is in fact the case, however, is a largely unexplored issue. Finally, since the literature on non-academic skills, competencies, and dispositions is somewhat underdeveloped conceptually, direct or even indirect measures of these skills have not been fully developed. This makes it difficult for researchers to obtain systematic data on an individual's "bundle" of skills, forcing a reliance on the few measures of academic skills that are available.

The effect of treating skills as one dimensional when in fact they are not, could have serious consequences for the policy inferences drawn from research. In a standard multiple regression model predicting (the natural logarithm of) an individual's hourly wage rate, academic ability seems to be an important factor. The widely cited work of Murnane and colleagues (Murnane & Levy, 1996; Murnane et al., 1995) suggests that basic mathematical skills of high school seniors (as proxied by an 8th-grade level test score of math skills) were more important predictors of wages six years after high school in the mid-1980s than in the late 1970s. This result was interpreted by the authors as an indication of the need to strengthen basic math skills through curriculum or other changes; however, the conclusion is derived from models in which the only individual skills measured are a subset of academic skills. It may be that math skills are highly correlated with other important skills used in the workplace, or that individual and family background characteristics partially proxy for non-academic skills, but these propositions have not been tested. It is possible that, if other skills could be accurately measured and included in the statistical models, the estimated effects of academic skills could change—they could disappear completely or become stronger, depending on the relationship between academic and non-academic skills. Even if the importance of academic math skills remained, the policy conclusion might be very different, depending on the relative value of academic and non-academic skills and our understanding of how best to develop and strengthen an individual's non-academic skills. The push for a highly skilled workforce leads to an emphasis on academics, not because we know that higher level academic skills are needed in work, but because that's how we measure "skill" in the education system, and because we know relatively little about how some other types of skills can be acquired in structured, school-related activities or programs.

The analyses are necessarily exploratory both because the conceptual work on non-academic skills is incomplete and because conventional datasets do not contain properly developed, direct measures of non-academic skills. In this chapter, we offer some evidence on two important questions that underlie this discussion:

1. What is the relationship of non-academic to academic skills? In other words, do students typically possess both types of skills, or is there a trade-off between academic and non-academic skills?
2. How do non-academic skills affect labor market performance? In particular, how are the results of traditional econometric analyses of the determinants of wages affected by more completely representing an individual's skill bundle?[14]

We believe that answering these questions is absolutely critical to developing sound educational policy. Current data does not allow definitive analyses of these issues. For example, although data permit us to paint a picture of students' academic, extracurricular, and work activities, these indicators are at best crude proxies for different kinds of skill. Further, our analyses of labor market performance is confined to wages and focused on one group of students, the non-college-bound; caution should therefore be exercised in generalizing to other outcomes or groups. Our initial results suggest the need for the development of a more rigorous conceptualization of different kinds of skills, consideration of how (if at all) they could be measured in large scale surveys, and a better understanding of the ways in which individuals develop these skills.

**Academic Skills and Formal Schooling**

Quantitative research on labor market performance has stressed the importance of quantity of schooling, and to a lesser extent the "quality" of schooling, as key predictors of an individual's wage, which is taken as a proxy for productivity (Altonji, 1995; Brewer, Brewer, Eide, & Ehrenberg, 1999; Brown & Corcoran, 1997; Crawford, Johnson, & Summers, 1997; Wise, 1975). For example, studies of changes in labor market returns to different education levels show an increasing payoff to a college education during the 1980s, caused by changes in both skill supply and demand (Bound & Johnson, 1992; Katz & Murphy, 1992; Levy & Murnane, 1992). Typical measures used in such studies include years of formal schooling, test scores, accumulated curriculum units, or years of formal training. In most of this work then, "education" is a proxy for "skill," and the implicit assumption is that these are primarily academic skills. At its crudest, years of education may be a proxy for skills. But what kind of skills? It captures "seat time" but does not distinguish between what has been taught, the quality of the

[14] Presumably individuals require many different kinds of skills to be successful in postsecondary education, as well as in the labor market. In principle, therefore, one could also examine the extent to which possessing non-academic skills enhanced entry to college, college GPA, and graduation rates.

learning experience, and whether the individual directly increased his or her knowledge or skills.[15] Given the emphasis in traditional school settings on academics, what such an indicator is really capturing is academic skill, or rather exposure (in time or content) to opportunities thought to enhance academic skill. Test scores may, depending on the nature of the test, measure an individual's level of academic achievement (viewed in part as an "output" of schooling) and/or cognitive ability. Many would argue that the types of test scores typically available in national data are used with too little attention to what the tests really measure; only limited indicators of academic proficiency are commonly collected. If the skills rewarded in the economy are really changing, new measures are needed: "The skills that are in increasing demand are often the kind of behavioral skills that have not typically been part of academic achievement assessments" (Capelli, 1996).

While research suggests that skills important to job performance may be multifaceted and complex, the conceptual distinctions among the different dimensions of skill are incomplete. While indicators of academic skills remain crude, they have been widely used in research; however, reliable and widely accepted measures of non-academic skills are in short supply. There are few "tests" of an individual's level of teamwork, personal qualities (honesty, self-management, responsibility), or communications skills.[16] Any researcher interested in the extent to which students currently possess non-cognitive skills and dispositions must, therefore, rely on proxies for them. For example, survey data often contains items relating to after-school extracurricular activities and part-time work in the labor market during high school, which may be regarded as opportunities to acquire and develop certain non-academic competencies. Although at first glance these may appear to be indirect indicators of non-academic skills, they are in many ways no less so than the equating of classroom seat time with academic skills. Clearly, classroom activity is not the only arena in which academic knowledge and abilities are developed; both academic and non-academic skills can be viewed as being acquired in numerous structured and unstructured settings at home, work, school, and other social settings. We cannot hope to directly capture these in survey data.

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[15] Altonji (1995) implicitly finds evidence for this. His results suggest that the returns to additional courses in academic subjects are small, far below the return to an additional year of high school. The key question is, "What explains the difference?"
[16] The Work Keys assessment, which was created in 1993 by ACT, gauges skills in locating and reading for information, applied math, listening, writing, teamwork, applied technology, and observation. Work Keys is not yet in widespread use in schools, although at least four states (Mississippi, Ohio, Tennessee, and West Virginia) use it as a high school exit requirement for vocational students. Employers are also beginning to review Work Keys scores before making hiring decisions. Unlike national tests of academic skills, such as NAEP, available Work Keys data do not yet provide a representative picture of work-related skill attainment.

### Extracurricular Activities and Labor Market Work While in School

In addition to the time with other families and in the classroom while at school, two other major ways in which students spend their time, particularly in the years directly preceding high school graduation and entry to postsecondary schooling or the labor market, are in extracurricular activities and part-time work while in school. National data reveal that as many as 80% of high school students participate in some form of extracurricular activity and about two-thirds of high school seniors work part-time.[17] Both activities have been the subjects of research ranging from the determinants of participation to the effects on students (e.g., Holland & Andre, 1987; Lillydahl, 1990; McNeal, 1995; Sabo, Melnick, & Vanfossen, 1993; Steinberg, Greenberger, Garduque, & McAuliffe, 1982). While rarely considered jointly, or viewed as ways of acquiring skills, the two activities have most commonly been studied in the context of their effect on students' academic outcomes—for example, whether participation in various extracurricular activities enhances or diminishes academic performance, or whether students who work more hours while in school are more likely to drop out of high school.

The predominant issue in these studies, then, is the complementarity or substitutability of schoolwork and extracurricular activities, or schoolwork and labor market work. In a narrow sense, all three compete for a student's time; in a broader sense, they might be viewed as different means of acquiring different skills—all ways of enhancing an individual's "skill bundle" albeit in different ways. Work in school may help "improve post-school transition to employment by accustoming youth to general work habits, values, and attitudes that would be expected of them in their adult occupations. In addition, work would provide youth with opportunities to assume greater responsibility, authority and interdependence" (Lillydahl, 1990, p. 308). Similarly, extracurricular activities may be viewed as providing "experiences that further the total development of individual students" (Holland & Andre, 1987, p. 438). Participation in sports, the most popular activity, is hypothesized to build character, improve self-discipline, and teach the value of teamwork (Spreitzer, 1994).

Several findings and issues are worth highlighting from this research; comprehensive reviews of the literature exist elsewhere. First, there is a lack of convincing evidence about the effects of both part-time extracurricular activities and work on a range of student outcomes ranging from aspirations, to college attendance, to test scores. All studies are forced to rely (in the absence of randomized experiments, which do not exist) on non-experimental data which easily establishes correlations among

[17] Figures on work during high school tend to differ between U.S. Department of Labor data and national education surveys. The tables in this chapter provide an indication of the level of activity for each based on NCES data.

variables, but it is hard to establish causal linkages. For example, much educational research reveals a positive correlation between participation in varsity sports and student outcomes (such as grades, the likelihood of enrolling in college, and earnings), but as Holland and Andre (1987) note "although such correlations have been shown to exist, the available research does not demonstrate convincingly that participation causes such desirable outcomes" (p. 447).[18] Statistically more complex studies such as Eide and Ronan (1998) find rather more mixed results.

On the relationship between labor market work while in high school and student achievement, much of the conventional wisdom that work has a positive effect on students has been based on "little empirical evidence" (Greenberger & Steinberg, 1986, p. 189). A review of the literature by Greenberger and Steinberg finds small but statistically weak evidence of some negative effects of work on student outcomes. This result has been confirmed in a number of more sophisticated studies (e.g., Lillydahl, 1990; Marsh, 1991), which find that modest amounts of work in school do not have deleterious effects. However, the negative effects of working are a function of the number of hours worked; Lillydahl (1990), for example, found that working more than 15 hours per week has negative consequences such as increased absence, less time spent on homework, and a lower GPA. Marsh (1991) confirms the negative effects but only for work during the school year.[19]

Second, both extracurricular and labor market activities are ones students voluntarily choose to undertake. Students are not compelled to be on the school football team, or play a musical instrument, or work on weekends in the local fast food store.[20] This means that analyses of extracurricular and work activity are plagued by self-selection problems. In other words, it is very difficult to disentangle the effect of participation in an activity from the possibility that the individuals participating are simply different in some way that is unobservable to the researcher. For example, the fact that there may be a negative correlation between hours of work while in high school and test scores may have nothing to do with the influence of work on academics, but instead simply reflect the fact that students who choose to work in high school are those with lower academic performance. Those participating in extracurricular activities may be the most energetic,

[18] Studies of extracurricular activities include Holland and Andre (1987), Mahoney and Cairns (1997), and McNeal (1995). Research on varsity sports includes Eide and Ronan (1998), Snyder and Spreitzer (1990), Sabo et al. (1993), Marsh (1993), Fejgin (1994), and Ewing (1995).

[19] See Stasz (1998) for a review of research on work-based learning.

[20] Of course, financial pressures may make work after school more likely, or an ambitious parent may insist on participation in an extracurricular activity, but there remains a degree of choice.

motivated students with few academic problems who are easily able to spend time on them without adverse effects on schoolwork; under such a scenario, the observed positive correlation between schoolwork and extracurricular activities has no causal interpretation. Few studies have adequately addressed this problem statistically. Those that have (e.g., Eide & Ronan, 1998) find far less robust positive effects of participation in sports. No study takes account of the fact that work during the school year and student achievement are likely to be simultaneously determined; and no prior research considers work in school, extracurricular activities, and work in the labor market as being simultaneously chosen by an individual.

Third, like opportunities to develop skills in family or classroom settings, the range and quality of experiences is likely to be immense. Just as the number of math courses a student has taken is a weak indicator of math skills, so too whether a student participated in the school band or on a sports team is likely to be a weak proxy for the extent to which teamwork skills have been learned. Although, in general, one would expect that individuals who participate in such activities are likely to have had the opportunity to develop social and teamwork skills (just as in general one would expect a student who has had more math courses to know more math), the relationship is not likely to be uniform. For extracurricular activities, there is a wide range of potential activities—academic clubs, varsity and intramural team and individual sports, drama, debate, band, cheerleading, and so on. One would expect the skills learned from these to vary. Gerber (1996), who uses the National Educational Longitudinal Study of 1988 (which is used in the present study) to examine extracurricular activities, finds that participation in school-related activities was more strongly associated (positively) with achievement than was participation in activities outside school. Unfortunately, this potentially interesting finding has to be treated with skepticism in that the estimation procedures used do not allow causality to be inferred.

Similarly, participation in the labor market could involve everything from working in a fast food restaurant, to playing in a ska band, to doing clerical work in an office, thus, generating a huge difference in the types of skills that may be acquired. Many students now also have the opportunity to participate in work activities that are in theory systematically related to schoolwork through co-op, internship, career magnets, and work-based learning programs (c.f. Stasz & Brewer, 1998). Measuring the quality of such work experiences is not easy; indeed, many studies are not even able to measure the intensity (i.e., number of hours) of work experience but, rather, simply have an indicator of work activity (Lillydahl, 1990). It may also be that extracurricular and work activities have different impacts on particular kinds of students. Lillydahl implicitly suggests, for example, that part-time work may increase the future opportunities for non-college-bound students, although this may depend on the extent to which their jobs provide general or specific training that complements academic schoolwork (p. 315). Eide and Ronan (1998) have found the effects of sports on earnings and other outcomes to vary considerably along racial/ethnic and gender lines.

## *Study Approach*

This report's fundamental premise is that skills are multidimensional. The preceding sections argue that, in the absence of a more rigorous conceptualization of different types of skills, and well-developed measures that capture them, we need to look to other possible proxies for skills. Just as variables such as test scores, curriculum indicators, and years of schooling serve as measures of academic skills, students' participation in extracurricular and part-time work activities may serve as measures of non-academic competence such as communication and teamwork skills. What is the implication of viewing skills in this way rather than as one dimensional? In a narrow sense, the answer to this question is that previous research—particularly quantitative research—on the effect of academic skills on labor market performance may have been misleading. We outline this argument in this chapter and, in doing so, the motivation for our empirical analyses becomes clear. Non-technical readers can skip the formal steps without loss of understanding in a broader sense, though one does not need formal statistical knowledge to realize that the policy implications could be profound. Focusing simply on academic skill development in education reform may cause a crucial component in preparing youth for the labor market to be ignored, and, in turn, may lead to a misplaced emphasis on academics. If non-academic skills are important and developed in arenas other than academic coursework, schools may wish to fundamentally redesign their priorities around a broader array of activities. The fact that American teenagers already spend a significant fraction of their time in extracurricular activities and in working part-time in the labor market (to a much greater degree than in other countries) may be *prima facie* evidence of the value of such activities.

Suppose individuals possess a "bundle" of knowledge, skills, and aptitudes that they bring to the labor market. These skills may be acquired through formal schooling, formal and informal training on the job, and a wide variety of other experiences. For simplicity, let's label these skills (S) as academic (A) and non-academic (N). Both these multifaceted skills may be rewarded in the labor market. In other words, an individual's wage (W) is a function of both types of skill, as well as many individual and/or job characteristics (X), and a random component ($\varepsilon$).[21]

(1) $Y_{ij} = \beta X_{ij} + \gamma S_j + \varepsilon_{ij}$

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[21] The outcome here is typically the natural logarithm of the hourly wage rate. Other outcomes, such as job status and the quality of work experiences, are clearly

If (1) is correctly specified, then standard Ordinary Least Squares (OLS) regression models will yield unbiased estimates of b and g, the effects of a change in individual/job characteristics, and in skills, on wages, other things equal, respectively. In most cases, however, the researcher is unable to include S in his or her model. In fact, non-academic skills are ignored, and the model is estimated with only variables for academic skills included. In other words, the true model is given by (2) but the researcher incorrectly estimates (3):

(2) $LOG\ WAGE = \beta X + \gamma_1 A + \gamma_2 N + \varepsilon$

(3) $LOG\ WAGE = \beta^* X + \gamma_1^* A + \upsilon$

Estimating (3) may yield biased estimates of the effects of both individual/job characteristics and academic skills on wages.[22] If characteristics in X and academic skills (A) are uncorrelated with excluded non-academic skills, then OLS estimation will yield consistent and unbiased estimates of $\beta$ and $\gamma_1$. (OLS gives estimates of the variance of $\beta$ and $\gamma_1$, however, which are biased upwards, thus preventing valid inferences about the estimated coefficients of either individual and family background variables or academic skills.) More likely, there will be a correlation between background characteristics and non-academic skills and between academic and non-academic skills. This means that standard OLS models will yield biased estimates of the effects of both other characteristics and academic skills on outcomes like wages.

Whether the effect of omitting non-academic skills from this kind of statistical model leads to biased coefficient estimates and, hence, faulty inferences for policy is an empirical issue. The magnitude and direction of the bias depends (as can be seen from footnote 23) on (1) the extent to which there is a correlation between academic and non-academic skills, and (2) the true relationship between non-academic skills and wages ($\gamma_2$). If, as seems plausible from prior research, non-academic skills can also have positive effects on wages ($\gamma_2 > 0$), the existence of a positive correlation between academic and non-academic skills suggests traditional model estimates will have *overstated* the importance of academic skills in determining wages. In other words, on the one hand, part of the estimated return to academic skills is in part the return to non-academics. On the

important; however, since wages are the outcome most widely studied in this context, and the most easily observable outcome, we frame the discussion in this section around wages as the outcome of interest.

[22] As is well known, the coefficients are given by

$$\beta^* = \beta + \gamma_2 (NN)^{-1} (NX)$$
$$\gamma_1^* = \gamma_1 + \gamma_2 (NN)^{-1} (NA)$$

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other hand, if academic and non-academic skills are negatively correlated, then the effect of academic skills on wages may have been *understated*. Bias in either direction could clearly lead to misleading policy inferences, so it is important to empirically investigate these relationships.

The key determinant of whether traditional analyses such as those discussed above yield incorrect statistical and policy inferences depends on the relationship between academic and non-academic skills, and between non-academic skills and labor market outcomes.[23] In other words,

- What is the relationship of non-academic to academic skills? Do students typically possess both types of skills, or is there a trade-off between academic and non-academic skills?
- How do non-academic skills affect labor market performance? In particular, how are the results of traditional econometric analyses of the determinants of wages affected by more completely representing an individual's skill bundle?

Since no well-developed measures of non-academic skills exist, tackling both these questions is difficult. A second best solution is to use participation in extracurricular and part-time work as proxies for non-academic skills. This is what is attempted in the remainder of the chapter.

## *Data*

For this study, we use two national databases which contain individual level longitudinal data on the high school classes of 1982 (High School and Beyond [HSB]) and 1992 (The National Educational Longitudinal Study of 1988 [NELS:88]). These data include detailed background characteristics of a large number of individuals, as well as information about school experiences and activities (academic and non-academic) and post-high school outcomes (college attendance, labor market experiences, and so on). These databases were designed to be comparable across cohorts; the use of two cohorts permits comparisons across time. In each case, we use the maximum sample size available after missing values are eliminated. A detailed explanation of how the samples were created is contained in Appendix II.

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[23] Of course, analyses of these questions must also be attentive to how the answers to these questions might vary systematically across groups. For example, is the relationship between academic and non-academic skills different for college-bound and non-college-bound students? Or do non-academic skills have a different payoff in different segments of the labor market? Further research is needed on these issues.

HSB contains information on nearly 15,000 individuals who were high school sophomores in 1980. Students were surveyed in 1980 and 1982 while in high school, supplying a large amount of information on family background, activities in school, part-time work, and academics (grades, courses taken). Most students completed standardized tests in both 10th and 12th grades,[24] and transcripts were obtained from many students indicating coursework taken. Follow-up information from the same students was obtained in 1984, 1986, and 1992 as the students entered the labor market or attended college. NELS:88 surveyed and tested about 24,000 8th-grade students in 1988, with smaller samples of the same students resurveyed and tested in the 10th and 12th grades; a 1994 follow-up provides post-high school outcomes. In addition to providing similar information to the HSB on family background, extracurricular, and other activities, parents were surveyed to provide more reliable measures of some variables (e.g., parental education, family income).

We make use of three sets of items on each survey relating to academic, extracurricular, and part-time work activities in high school. These may be viewed as proxies for the set of skills—academic and non-academic—an individual might possess. Table 4.1 identifies the major potentially useful variables, although not all are used in the analyses that follow. (Detailed variable definitions are found in Appendix II.) The first panel of the table lists some academic skill measures—test scores, curriculum indicators, and so on. For the HSB, we use a mathematics score for the 10th- and 12th-grade test. NELS:88 contains four subject matter tests given to students in math, science, history, and reading. There are numerous available coursetaking indicators generated from student transcript data, but for simplicity we focus on the number of credits in mathematics and English, calculated using a method designed to be comparable across surveys. Grade point average is not calculated in a consistent fashion across surveys.

The second panel lists various variables describing an individual's participation in extracurricular activities and part-time work while in high school. On HSB and NELS:88, these items are self-reported and may be collected at the 10th- and/or 12th-grade levels (and in the case of NELS:88, also in the 8th grade). On the HSB, individuals are asked whether they participate in a range of extracurricular activities, including drama/plays, band/orchestra, student government, student newspaper, and varsity sports, in both 10th and 12th grades (with some differences in items across grades). In all, students could check 12 possible activities in the 10th grade

[24] HSB cognitive tests were given in vocabulary, reading, and mathematics. In order to parallel our analyses of NELS:88, we report results using the mathematics raw test score number correct. Results using a valid composite score calculated by NCES that combines a student's score on each of these tests does not affect the results presented.

**Table 4.1.** Possible Proxies of Skill in National Data

**Academic Measures**

*Cognitive Ability Test Score*
- Absolute score
- Relative score (percentile rank)

*Subject Matter/Achievement Test Score*
- Absolute score
- Relative score (percentile rank)
- Subject – math, science, reading, history, and so on
- Timing – grade test taken

*Grade Point Average*
- Current
- Cumulative

*Curriculum Indicators*
- Course-taking patterns (level, sequence)
- Units completed by subject

*Years of Schooling Completed*

*Quality of Schooling*

**Non-Academic Measures**

*Extracurricular Activities in High School*
- Participated or not
- Total number – current, cumulative
- Timing – grade activity undertaken
- Hours per week – current week, average
- Type of activity – band, drama, newspaper, cheerleading, varsity/intramural team/ individual sports, student government, volunteer

*Part-Time Work in the Labor Market While in High School*
- Participate or not
- Timing – grade activity undertaken
- School year versus summer
- Hours per work – current week, average
- Wage on job
- Training received on job
- Type of job

and 17 possible activities in the 12th grade, allowing the creation of a variable for the total number of activities participated in. On the NELS:88, a similarly broad array of activities was asked about (31 in the 8th grade, 18 in the 10th grade, and 14 in the 12th grade; see Appendix II), but two significant improvements were made over the HSB data.

First, students in the first and second follow-ups were asked to indicate how much total time they spent on all school-sponsored extracurricular activities in a typical week (albeit categorical)—giving an indication of the intensity of involvement. Second, also in the first and second follow-up, students indicating they did not participate were able to answer that this was the case because their school did not offer the activity. On the HSB, non-interest in the activity and its non-availability cannot be separated from each other. Work-related items on NELS:88's 8th-, 10th-, and 12th-grade surveys included the number of hours per week worked for pay on the present or most recent job, the hourly wage received, and the type of job.[25] The HSB also asks about hours of work and wage on the job. The 1994 follow-up survey

[25] Chores done around the house were not included.

included additional information about work and employers—on-site and off-site formal and informal training and education programs, and hours per week attending the training program.

We now turn to some empirical evidence, using the HSB and NELS:88 data, on the two questions of interest—the relationship between academic and non-academic skills, and between non-academic skills and wages, as proxied by these academic, extracurricular, and part-time work indicators.

## *Characterizing Individuals' Skill Bundles*

In this section, we attempt to characterize individuals' skill bundles. We do so by examining student survey items relating to academics, extracurricular activities, and part-time work. In addition to mapping out the kinds of academic skills students have in terms of test scores, grades, and accumulated curriculum units, we also examine participation in extracurricular activities and work in after-school jobs. As noted earlier, there are some differences between cohorts in the measures available, so we present the results for each cohort separately. The figures reported are based on unweighted tabulations of the data, although all statistics were also calculated using sample weights supplied by NCES to make the figures "nationally representative." Few differences were found between the two sets of figures, and we prefer to report in the text the unweighted ones.[26] In this section, we rely on descriptive statistics (means, frequencies, and correlations) in an attempt to discern patterns in the data; the section that follows contains multivariate analyses.

We describe skill bundles in three ways. First, we divide the sample according to the individual's *education status*—whether the individual obtained a high school diploma with their graduating class ("high school graduate"), received a GED ("GED"), had failed to complete high school ("dropout"), or was an early graduate or other by 1982 in the HSB case, or by 1992 in the NELS:88 case.[27] Tables 4.2A and 4.2B show the means and frequencies of the measures of academics, extracurricular activities, and part-time work for the 1982 and 1992 high school classes, respectively.

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[26] HSB oversamples private school students and Hispanics. In order to make sample statistics representative of the national population of 10th or 12th graders, sample weights are supplied by NCES. However, in longitudinal data such as these, calculation of accurate weights for each of the subsamples of interest to us is problematic, and it is not at all clear that weighted data give a representative picture. Weights are not used in regression models since the models control for background factors that may affect the likelihood an individual is sampled.

[27] We also explored a similar but alternative definition of education status based on high school educational attainment by 1984/1994. This alternative definition expanded the GED category but did not substantively change any of the results.

Second, we divide the sample according to academic ability as measured by the mathematics test scores in HSB and NELS:88[28]; these results are in Tables 4.3A and 4.3B. Third, we divide the sample according to their status two years after high school. Individuals' primary activity is used to classify status as out of the labor force, unemployed, attending a two-year college, four-year college, or employed (see Appendix II for detailed definitions). These tables are designed to illustrate the types of skills individuals have. These groupings are chosen because of the traditional focus on academic and labor market outcomes and our interest in the relationships between non-academic skills and these indicators.[29]

Turning first to the results by education level, Tables 4.2A and 4.2B confirm that high school graduates have higher test scores and grade point averages than high school dropouts. For example, on the NELS:88 in all cases, high school graduates have statistically significant higher test scores in math and reading at each grade level than do dropouts ($p < .0001$ in every case). A similar pattern exists for the HSB cohort. In some cases, the differences are large (one standard deviation or more). The tables also clearly suggest that high school completers have taken significantly more coursework in English and math than dropouts; interestingly (since these measures are comparable over time), over the 1982-1992 period, the gap in coursework between graduates and dropouts actually widened. GED holders and early graduates fall somewhere between these two extremes on all measures. In the NELS, for example, GEDs are statistically different from high school graduates for all test score measures ($p < .0001$), statistically different from dropouts at the $p < .0001$ level for all test scores, and at the $p < .08$ level for units in English and $p < .0002$ level for units in mathematics. For the HSB cohort, each group is statistically significantly different from the other at the $p < .0001$ level.

A less robust picture emerges when we turn to extracurricular activities. The HSB and NELS:88 data should not be compared for changes across time given differences in the way the survey items were framed. For dropouts and early graduates, 12th-grade figures can be calculated for only a small number of remaining students, so 10th-grade figures are more appropriate. There appears to be a positive relationship between participation in some activities and education status, particularly in the 1982 data. (In all cases, the differences are statistically significant at the $p < .0001$ level.) For the 1992 cohort, only in sports do high school graduates participate to a greater degree; overall, though, the number of activities is statistically significantly higher for graduates in both cohorts. Interestingly,

[28] Test results using the reading test to define quartiles are also available but show similar patterns to those reported here.

[29] Clearly, many other crosstabulations are possible. For example, we could examine the skill bundles of separate demographic groups—men versus women, African-Americans versus Hispanics versus whites, and so on.

Table 4.2A

Academic, Extracurricular, and Work Indicators, High School Class of 1982, by Education Level

| | Dropout | High School Graduate | GED Holder | Early Graduate/Other |
|---|---|---|---|---|
| **Academic** | | | | |
| 10th grade math raw score Maximum number right = 18 | 6.45 (2.94) | 10.10 (4.01) | 7.87 (3.94) | 8.54 (3.76) |
| 12th grade math raw score Maximum number right = 38 | 12.60 (4.81) | 21.25 (8.04) | 16.09 (6.59) | 17.09 (7.22) |
| GPA | 1.43 (0.69) | 2.55 (0.71) | 1.70 (0.80) | 2.07 (0.85) |
| English credits | 1.86 (1.12) | 3.91 (1.14) | 2.19 (1.32) | 2.90 (1.37) |
| Math credits | 1.21 (0.83) | 2.71 (1.22) | 1.44 (0.90) | 1.87 (1.10) |
| **Extracurricular** | | | | |
| 10th grade team sport | 38.18 | 57.11 | 42.24 | 46.34 |
| 12th grade varsity sport | - | 35.87 | 20.00 | 26.73 |
| 10th grade drama | 7.34 | 11.58 | 10.33 | 9.69 |
| 12th grade drama | - | 14.49 | 17.14 | 12.63 |
| 10th grade band | 11.76 | 16.40 | 11.99 | 14.90 |
| 12th grade band | - | 13.91 | 2.94 | 14.91 |
| 12th grade school newspaper | - | 20.29 | 14.71 | 16.05 |
| 12th grade student government | - | 18.54 | 8.57 | 14.97 |
| 10th grade total extracurricular | 1.98 | 2.45 | 2.23 | 2.19 |
| 12th grade total extracurricular | - | 3.35 | 2.56 | 2.81 |
| **Work** | | | | |
| 10th grade hours | 15.05 (12.28) | 10.67 (10.91) | 16.01 (12.55) | 14.08 (11.88) |
| 12th grade hours | - | 11.51 (12.07) | 15.57 | 13.28 (13.09) |
| 10th grade wage | 2.35 (1.25) | 2.02 (1.32) | 2.49 (1.21) | 2.28 (1.29) |
| 12th grade wage | - | 3.54 (0.90) | 3.93 (0.70) | 3.65 (0.82) |

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## Table 4.2B
## Academic, Extracurricular, and Work Indicators, High School Class of 1992, by Education Level

| | Dropout | High School Graduate | GED Holder | Early Graduate/Other |
|---|---|---|---|---|
| **Academic** | | | | |
| 8th grade math | 25.34 (7.2) | 37.45 (11.9) | 30.57 (9.0) | 31.03 (10.3) |
| 10th grade math | 28.67 (9.2) | 45.11 (13.6) | 35.35 (11.0) | 35.75 (12.6) |
| 12th grade math | 31.35 (9.4) | 49.60 (14.3) | 38.30 (10.4) | 38.43 (12.4) |
| 8th grade reading | 19.74 (6.2) | 27.83 (8.6) | 23.97 (7.4) | 23.54 (7.7) |
| 10th grade reading | 21.51 (7.7) | 31.38 (9.8) | 26.48 (8.9) | 25.72 (9.5) |
| 12th grade reading | 23.04 (8.1) | 33.63 (10.1) | 29.21 (9.1) | 27.80 (9.5) |
| GPA* | 5.27 (16.3) | 14.67 (28.6) | 5.79 (16.4) | 9.75 (22.7) |
| English credits | 1.47 (1.2) | 4.01 (1.0) | 1.59 (1.2) | 2.49 (1.4) |
| Math credits | 1.03 (0.9) | 3.18 (1.0) | 1.25 (1.0) | 1.84 (1.1) |
| **Extracurricular** | | | | |
| 10th grade team sport | 36.27 | 45.21 | 30.99 | 36.18 |
| 12th grade team sport | 34.16 | 33.08 | 39.56 | 40.88 |
| 10th grade drama | 23.16 | 17.06 | 18.90 | 20.13 |
| 12th grade drama | 24.73 | 21.50 | 35.11 | 31.98 |
| 10th grade band | 27.42 | 27.06 | 25.64 | 24.37 |
| 12th grade band | 28.03 | 25.90 | 37.50 | 32.82 |
| 10th grade student government | 18.45 | 14.62 | 14.74 | 13.21 |
| 12th grade student government | 21.98 | 21.84 | 29.02 | 28.57 |

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**Table 4.2B (cont.)**

| | Dropout | High School Graduate | GED Holder | Early Graduate/Other |
|---|---|---|---|---|
| **Extracurricular (cont.)** | | | | |
| 10th grade total activities | 0.89 (1.67) | 2.21 (1.96) | 0.90 (1.57) | 1.28 (1.80) |
| 12th grade total activities | 0.29 (0.98) | 2.31 (1.97) | 0.47 (1.23) | 0.89 (1.51) |
| 10th grade mean hours participated per week | 1.23 (3.28) | 3.79 (5.45) | 1.60 (4.00) | 2.12 (4.40) |
| 12th grade mean hours participated per week | 2.36 (5.11) | 5.26 (6.57) | 2.32 (5.17) | 3.89 (6.33) |
| Performed volunteer or service community work | 23.81 | 45.33 | 26.01 | 28.65 |
| **Work** | | | | |
| 8th grade hours worked per week | 5.687 (7.04) | 4.374 (5.81) | 6.171 (7.05) | 5.229 (6.70) |
| 10th grade hours worked per week | 22.601 (11.23) | 17.522 (11.42) | 23.049 (11.08) | 20.743 (11.55) |
| 12th grade hours worked per week | 18.728 (13.41) | 13.908 (11.06) | 21.717 (15.09) | 15.690 (13.48) |
| 10th grade earnings per hour | 4.447 (1.71) | 4.240 (1.74) | 4.505 (1.78) | 4.408 (1.66) |
| 12th grade earnings per hour | 5.188 (1.87) | 5.291 (1.93) | 5.572 (2.58) | 5.346 (1.83) |

*Cumulative grade point average for last year of school attended. Cumulative GPA has not been standardized. Some values exceed 100% because of quality points awarded for advanced courses.

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the likelihood that high school graduates volunteer in the community is almost twice as much as dropouts, and GED and early graduates/other have levels of participation similar to dropouts. In terms of work, a different pattern emerges—academically oriented students who ultimately graduate high school work less in the 10th grade while in high school than dropouts ($p < .0001$) in both the HSB and NELS:88. Differences among the groups in terms of wages are small, but, in the case of the 1992 cohort, are still statistically different for high school graduates versus dropouts ($p < .0011$) and high school graduates versus GED holders ($p < .0091$); GED holders and dropouts do not have statistically different hours ($p < .6082$) or pay ($p < .6122$). Overall, the tables suggest that individuals of different education levels clearly possess bundles of skills with contrasting components. Those finishing high school are likely to have stronger academics, moderately more extracurricular activities and less part-time work.

The pattern of indicators by academic ability is shown in Table 4.3A for the 1982 cohort and Table 4.3B for the 1992 cohort. Not surprisingly, the academic measures increase positively with ability quartile—in other words, there is a strong positive association between test score, GPA, and coursetaking in math and English. (Differences between top and bottom quartiles are statistically significantly different from each other on all measures at the $p < .0001$ level.) The extracurricular measures suggest a positive relationship with ability—those in the top test score quartile are more likely to participate in most extracurricular activities ranging from team sports to drama and student government, with the biggest differences for the latter. Overall, the difference between top and bottom quartiles in the number of activities participated in is small in 10th and 12th grades for the 1982 cohort (but still statistically significant at the $p < .0001$ level), and is somewhat larger in 1992 (but with a large statistically significant difference in the average number of hours, which number about two hours per week for bottom quartile versus five hours per week for the top quartile in the 10th grade, for example). In terms of hours of work, the negative correlation with academics is clear; although NELS data show that it strengthens considerably as the students move through high school. In the 8th grade, the mean hours worked for all students is between four and five per week, and the difference between top and bottom ability quartile is statistically significant only at the $p < .0055$ level; for the 10th and 12th grades, the differences are statistically different at the $p < .0001$ level.

These results indicate, then, that the bundle of attributes possessed by students of different ability (on average) are quite different—lower test score students tend to have weak academics, more extracurricular experiences, and less part-time work.

The choices students make after high school reflect to a large extent the skill set they have available to them—the most academically able, for instance, are most likely to go to a four-year college or university, other

Table 4.3A
Academic, Extracurricular, and Work Indicators, High School Class of 1982, by 12th-Grade Mathematics Test Score Quartile

| | Quartile 1 (Low) | Quartile 2 | Quartile 3 | Quartile 4 (High) |
|---|---|---|---|---|
| Academic | | | | |
| GPA | 1.83 (0.7) | 2.23 (0.7) | 2.58 (0.6) | 3.05 (0.6) |
| English credits | 3.21 (1.5) | 3.65 (1.4) | 3.85 (1.2) | 3.98 (1.0) |
| Math credits | 1.72 (1.0) | 2.15 (1.1) | 2.73 (1.1) | 3.55 (1.1) |
| Extracurricular | | | | |
| 10th grade sport | 47.01 | 51.19 | 57.51 | 63.26 |
| 12th grade varsity sport | 30.43 | 30.95 | 36.54 | 42.89 |
| 12th grade other sport | 37.09 | 39.06 | 42.09 | 47.18 |
| 10th grade drama | 8.54 | 9.60 | 11.00 | 15.36 |
| 12th grade drama | 11.78 | 11.75 | 13.84 | 18.01 |
| 10th grade band | 13.11 | 14.74 | 16.92 | 18.64 |
| 12th grade band | 12.71 | 12.19 | 14.92 | 14.54 |
| 12th grade school newspaper | 15.52 | 17.54 | 21.17 | 26.45 |
| 12th grade student government | 13.00 | 15.49 | 18.16 | 26.11 |
| 10th grade total | 2.28 | 2.32 | 2.43 | 2.54 |
| 12th grade total | 2.93 | 3.07 | 3.27 | 3.85 |
| Work | | | | |
| 10th grade hours | 12.55 (12.0) | 11.55 (11.4) | 11.17 (11.0) | 10.18 (10.5) |
| 12th grade hours | 23.27 (12.9) | 21.77 (11.6) | 19.72 (10.9) | 17.52 (10.2) |
| 10th grade wage | 2.15 (1.3) | 2.03 (1.3) | 2.02 (1.3) | 2.05 (1.3) |
| 12th grade wage | 3.52 (0.9) | 3.53 (0.9) | 3.54 (0.9) | 3.59 (0.9) |

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## Table 4.3B
## Academic, Extracurricular, and Work Indicators, High School Class of 1992, by 12th-Grade Mathematics Test Score Quartile

| | Quartile 1 (Low) | Quartile 2 | Quartile 3 | Quartile 4 (High) |
|---|---|---|---|---|
| **Academic** | | | | |
| 8th grade math | 24.34 (5.3) | 30.39 (6.3) | 38.04 (7.4) | 50.15 (8.1) |
| 10th grade math | 26.48 (5.4) | 37.39 (6.7) | 47.23 (6.5) | 60.11 (5.9) |
| 12th grade math | 27.72 (4.1) | 41.04 (3.6) | 52.62 (3.3) | 66.24 (4.8) |
| 8th grade reading | 19.76 (5.56) | 24.23 (6.6) | 28.07 (7.1) | 34.81 (6.7) |
| 10th grade reading | 20.80 (6.4) | 27.09 (7.5) | 32.62 (7.8) | 39.71 (6.5) |
| 12th grade reading | 21.98 (7.1) | 29.52 (7.8) | 35.18 (7.7) | 42.07 (6.08) |
| GPA* | 11.32 (25.4) | 13.34 (2.70) | 13.83 (27.7) | 17.34 (31.3) |
| English credits | 3.16 (1.5) | 3.73 (1.2) | 4.07 (.9) | 4.21 (.8) |
| Math credits | 2.04 (1.1) | 2.73 (1.0) | 3.30 (.9) | 3.83 (.8) |
| **Extracurricular** | | | | |
| 10th grade team sport | 42.56 | 41.19 | 44.18 | 47.50 |
| 12th grade team sport | 29.82 | 30.24 | 33.85 | 35.68 |
| 10th grade drama | 18.95 | 15.08 | 15.03 | 16.80 |
| 12th grade drama | 14.81 | 14.26 | 16.94 | 22.16 |
| 10th grade band | 26.49 | 24.87 | 25.37 | 28.78 |
| 12th grade band | 20.93 | 21.09 | 21.30 | 25.13 |
| 10th grade student government | 14.37 | 11.96 | 11.84 | 15.75 |
| 12th grade student government | 12.82 | 14.92 | 17.29 | 22.50 |

### Table 4.3B (cont.)

| | Quartile 1 (Low) | Quartile 2 | Quartile 3 | Quartile 4 (High) |
|---|---|---|---|---|
| **Extracurricular (cont.)** | | | | |
| 10th grade total activities | 1.57 (1.94) | 1.87 (1.88) | 2.27 (1.86) | 2.83 (1.94) |
| 12th grade total activities | 1.50 (1.84) | 1.94 (1.89) | 2.42 (1.89) | 3.15 (1.91) |
| 10th grade mean hours participated per week | 1.96 (4.14) | 3.13 (5.11) | 4.14 (5.65) | 5.04 (5.83) |
| 12th grade mean hours participated per week | 3.26 (5.87) | 4.26 (6.09) | 5.32 (6.38) | 7.06 (6.92) |
| Performed volunteer or service community work | 24.10 | 35.32 | 45.01 | 63.28 |
| **Work** | | | | |
| 8th grade hours worked per week | 4.520 (6.17) | 4.570 (6.03) | 4.608 (5.93) | 4.197 (5.57) |
| 10th grade hours worked per week | 20.094 (11.79) | 18.800 (11.52) | 17.451 (11.28) | 15.952 (11.36) |
| 12th grade hours worked per week | 16.257 (12.22) | 15.610 (11.12) | 13.745 (10.65) | 10.599 (9.821) |
| 10th grade earnings per hour | 4.268 (1.67) | 4.201 (1.67) | 4.164 (1.75) | 4.292 (1.88) |
| 12th grade earnings per hour | 5.179 (1.99) | 5.165 (1.79) | 5.260 (1.94) | 5.356 (1.98) |

*Cumulative grade point average for last year of school attended. Cumulative GPA has not been standardized. Some values exceed 100% because of quality points awarded for advanced courses.

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things being equal. Those with the weakest skills presumably have a higher probability of ending up being unemployed. How do individuals with these outcomes compare on their bundles of academic, extracurricular, and part-time work experiences? Tables 4.4A and 4.4B shed some light on this issue.

Those who ultimately go on to a four-year college have by far the highest test scores, curriculum credits, and GPAs. Those who enter the labor market clearly rank lower in academics than those who attend two- or four-year colleges but above those who are unemployed or out of the labor force. Interestingly, those who are employed generally have lower or comparable extracurricular participation—other than sports—to those who are unemployed, in both the HSB and NELS:88 data. (In most cases, there is no statistically significant difference between the groups.) Those who attend four-year colleges are by far the most active in all extracurricular activities. Those employed directly after high school (in both cohorts), however, have worked considerably more hours than other groups while in high school, particularly in their senior year. This is consistent with the idea that part-time work is a way of transitioning out of school for this group of students.

The tabulations suggest that individuals clearly possess, on average, a bundle of experiences that differ among individual students and contain some degree of complementarity and substitutability. In other words, although there may be some students who have high test scores and academic course credits, numerous extracurricular activities, and a great deal of part-time work experience, the more common pattern is to have either high academics and high extracurriculars, or low academics and high part-time work experience. For example, in the NELS:88 data, the underlying correlation matrix suggests that there is a weak positive correlation between math 12th-grade test score and hours of extracurricular activities in the 12th grade ($r = .22$, $p < .0001$) and weak negative correlation with hours of work in the 12th grade ($r = -.21$, $p < .0001$). Extracurricular activities and hours of part-time work are negatively correlated in the 12th grade ($r = -.15$, $p < .0001$). A very similar pattern exists in the HSB data.

## *Multidimensional Skills and Student Outcomes*

In this section, we offer some preliminary evidence on whether labor market outcomes are related not just to academic skills, but also to non-academic skills. We look only at the group of students who graduate high school with their class and go directly into the sub-baccalaureate labor market directly after high school. This is done for several reasons. First, the NELS:88 data only contain information on students two years after high school, so that labor market information is not yet available for students who go on to college. (On the other hand, the HSB data only contain earnings—rather than wage—data from 1992, ten years after high school graduation, and no hours worked information, so it is less than ideal;

**Table 4.4A**

**Academic, Extracurricular, and Work Indicators, High School Class of 1982, by Post-High School Activity**

| | Out of Labor Force | Unemployed | Employed | Attending 4-Year College | Attending 2-Year College |
|---|---|---|---|---|---|
| **Academic** | | | | | |
| 10th grade math raw score (maximum number right = 18) | 7.98 (3.85) | 7.39 (3.61) | 8.81 (3.76) | 12.28 (3.55) | 10.15 (3.72) |
| 12th grade math raw score (maximum number right = 38) | 16.24 (7.37) | 14.60 (6.35) | 18.06 (7.18) | 26.54 (6.98) | 21.40 (7.02) |
| GPA | 2.11 (.8) | 1.87 (.8) | 2.24 (.7) | 2.98 (.6) | 2.55 (.0) |
| English credits | 3.27 (1.4) | 3.18 (1.5) | 3.48 (1.3) | 4.11 (1.1) | 3.90 (1.1) |
| Math credits | 2.09 (1.2) | 1.82 (1.1) | 2.15 (1.2) | 3.43 (1.1) | 2.72 (1.1) |
| **Extracurricular** | | | | | |
| 10th grade team sport | 48.27 | 44.59 | 50.49 | 64.68 | 55.67 |
| 12th grade varsity sport | 31.75 | 26.92 | 30.48 | 46.51 | 32.52 |
| 12th grade other sport | 40.25 | 33.82 | 37.97 | 47.83 | 40.16 |
| 10th grade drama | 9.92 | 8.00 | 8.54 | 16.33 | 9.83 |
| 12th grade drama | 11.55 | 11.82 | 11.23 | 20.10 | 12.88 |
| 10th grade band | 15.45 | 14.98 | 13.48 | 19.45 | 15.97 |
| 12th grade band | 14.82 | 13.33 | 11.65 | 16.51 | 14.51 |
| 12th grade school newspaper | 18.29 | 15.69 | 15.33 | 30.51 | 17.63 |
| 12th grade student government | 13.33 | 12.38 | 13.36 | 28.64 | 16.39 |
| 10th grade total extracurricular | 2.33 (2.0) | 2.28 (1.9) | 2.20 (1.9) | 2.73 (1.8) | 3.30 (1.7) |
| 11th grade total extracurricular | 3.18 (2.7) | 2.84 (2.7) | 2.85 (2.0) | 9.18 (2.5) | 3.13 (2.4) |
| **Work** | | | | | |
| 10th grade hours | 11.45 (11.0) | 11.86 (11.8) | 12.83 (11.7) | 9.37 (10.2) | 10.29 (10.8) |
| 12th grade hours | 10.23 (12.2) | 10.82 (13.2) | 13.51 (12.7) | 9.63 (11.7) | 11.70 (11.5) |
| 10th grade wage | 1.97 (1.3) | 2.06 (1.3) | 2.20 (1.3) | 1.94 (1.3) | 2.00 (1.35) |
| 12th grade wage | 3.46 (.9) | 3.35 (1.0) | 3.57 (.9) | 3.55 (.9) | 3.57 (.9) |

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## Table 4.4B
## Academic, Extracurricular, and Work Indicators, High School Class of 1992, by Post-High School Activity

| | Out of Labor Force | Unemployed | Employed | Attending 4-Year College | Attending 2-Year College |
|---|---|---|---|---|---|
| **Academic** | | | | | |
| 8th grade math | 29.85 (10.3) | 28.16 (9.2) | 31.38 (9.8) | 43.90 (11.3) | 35.30 (10.4) |
| 10th grade math | 35.22 (12.7) | 32.71 (11.8) | 37.53 (12.2) | 52.96 (11.5) | 42.91 (12.1) |
| 12th grade math | 39.12 (13.7) | 36.35 (12.5) | 41.48 (12.7) | 58.21 (11.7) | 47.25 (12.4) |
| 8th grade reading | 23.18 (7.9) | 21.24 (7.1) | 23.87 (7.7) | 31.89 (7.9) | 26.74 (7.9) |
| 10th grade reading | 25.77 (9.4) | 23.74 (8.7) | 26.64 (9.2) | 36.40 (8.4) | 29.98 (9.1) |
| 12th grade reading | 28.31 (9.9) | 25.84 (9.8) | 29.04 (9.5) | 38.56 (8.6) | 32.31 (9.2) |
| GPA* | 12.88 (26.8) | 11.62 (25.4) | 11.78 (25.4) | 17.96 (31.9) | 11.87 (25.1) |
| English credits | 2.81 (1.6) | 2.72 (1.6) | 3.32 (1.4) | 4.21 (.8) | 3.95 (1.0) |
| Math credits | 2.08 (1.3) | 1.93 (1.3) | 2.37 (1.2) | 3.72 (.8) | 3.05 (1.0) |
| **Extracurricular** | | | | | |
| 10th grade team sport | 37.34 | 37.27 | 39.90 | 50.48 | 43.81 |
| 12th grade team sport | 33.59 | 31.65 | 33.14 | 40.93 | 36.18 |
| 10th grade drama | 18.77 | 20.62 | 16.81 | 18.42 | 16.79 |
| 12th grade drama | 21.59 | 22.36 | 20.21 | 24.45 | 22.39 |
| 10th grade band | 27.27 | 27.66 | 24.58 | 29.56 | 26.73 |
| 12th grade band | 27.92 | 26.92 | 23.96 | 28.47 | 27.05 |
| 10th grade student government | 13.60 | 16.59 | 11.76 | 18.59 | 14.10 |
| 12th grade student government | 20.81 | 17.29 | 18.56 | 27.44 | 21.09 |

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Table 4.4B (cont.)

| | Out of Labor Force | Unemployed | Employed | Attending 4-Year College | Attending 2-Year College |
|---|---|---|---|---|---|
| **Extracurricular (cont.)** | | | | | |
| 10th grade total activities | 1.27 (1.77) | 1.29 (1.82) | 1.60 (1.83) | 2.75 (1.98) | 2.03 (1.93) |
| 12th grade total activities | 0.97 (1.61) | 1.01 (1.58) | 1.39 (1.73) | 3.05 (1.96) | 2.10 (1.94) |
| 10th grade mean hours participated per week | 1.96 (4.20) | 1.76 (3.80) | 2.57 (4.68) | 5.06 (5.87) | 3.54 (5.44) |
| 12th grade mean hours participated per week | 3.08 (5.24) | 2.94 (5.44) | 3.81 (6.09) | 7.08 (6.88) | 4.79 (6.31) |
| Performed volunteer or service community work | 33.42 | 26.06 | 31.89 | 61.22 | 40.58 |
| **Work** | | | | | |
| 8th grade hours worked per week | 4.126 (5.62) | 4.587 (6.33) | 5.303 (6.58) | 4.022 (5.44) | 4.385 (5.90) |
| 10th grade hours worked per week | 18.925 (11.46) | 20.101 (12.07) | 19.911 (11.39) | 16.155 (11.37) | 17.463 (11.30) |
| 12th grade hours worked per week | 14.106 (12.62) | 14.974 (12.83) | 17.333 (11.80) | 10.819 (10.01) | 14.711 (10.46) |
| 10th grade earnings per hour | 4.133 (1.71) | 4.353 (1.87) | 4.293 (1.65) | 4.285 (1.84) | 4.035 (1.73) |
| 12th grade earnings per hour | 5.009 (2.05) | 5.018 (1.73) | 5.296 (1.88) | 5.398 (2.08) | 5.232 (1.77) |

*Cumulative grade point average for last year of school attended. Cumulative GPA has not been standardized. Some values exceed 100% because of quality points awarded for advanced courses.

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see below.)[30] Second, this sample restriction has the advantage of reducing heterogeneity in the sample—we are comparing a group with identical education and almost identical labor market experience levels. This reduces the likelihood that omitted factors bias our estimated results. It also means, of course, that one should not generalize from the results presented here to other populations such as high school dropouts or college-bound youth.

We confine our attention to the wage rates earned by individuals two years after high school. Examining the wages of students just two years after high school is problematic in part because previous research has suggested that this may not necessarily be an indicator of long-term success (Murnane et al., 1995). Some students in our sample will no doubt ultimately return to college and achieve greater earning potential than is indicated here, and the variation among the sample used in terms of wages will grow as their careers develop. In addition, of course, wages are only one indicator of labor market performance, and subsequent studies might look at wage growth, job status, job satisfaction, or other indicators.

Tables 4.5 and 4.6 show selected estimated regression coefficients from wage regressions for the variables of interest. As is standard in this type of study, we report the results separately for men and women. Major differences in the labor force behavior of men and women mean that pooling the two groups can yield misleading results. Table 4.5A shows the results for HSB men, Table 4.5B for NELS:88 men, Table 4.6A for HSB women, and Table 4.6B for NELS:88 women. All the HSB and NELS:88 models include a standard set of background control variables as noted in the notes to the tables.[31] The tables report a selection of all the models estimated, limiting attention to a manageable number of measures—mathematics test score in the 12th grade, mathematics units, 12th-grade total number of extracurricular activities, 12th-grade hours spent on extracurricular activities, and 12th-grade hours of work. (Other results not shown that are of interest—for example, using 10th-grade extracurricular activities and work, or the reading test score—will be discussed only to the extent that they yield contrasting findings to those reported in the tables.)

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[30] As an alternative, one could examine the senior cohort of HSB—that is, students in the high school class of 1980. For this cohort, labor market outcome data, including hourly wage rates, exist for the sample, six years after high school graduation. This is the sample used by Murnane et al. (1995). We have not analyzed this sample here because we wanted to examine the range of academic, extracurricular, and work experiences of students before the 12th grade, which is only possible with the HSB sophomore cohort.

[31] The adjusted $r^2$ for these models indicate that the explanatory variables can generally explain less than 5% of the variance in log wages. This is typical of these kinds of cross section log wage models.

## Table 4.5A
**Selected Determinants of Hourly Wage Rates Two Years After High School, 1982 High School Graduates, Men (absolute value t statistics)**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| 12th grade math test score | -.001 (.182) | -.000 (.109) | -.001 (.190) | .001 (.183) | .000 (.158) |
| Number of mathematics course credits | — | -.003 (.132) | — | — | — |
| 12th grade total extracurricular activities | — | — | .001 (.163) | — | .003 (.285) |
| 12th grade hours of work | — | — | — | .007 (4.158) | .007 (4.160) |

Sample size 1,269, male high school graduates who entered the labor market directly after high school only.

## Table 4.5B
**Selected Determinants of Hourly Wage Rates Two Years After High School, 1992 High School Graduates, Men (absolute value t statistics)**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| 12th grade mathematics test score | -0.002 (1.532) | -0.002 (1.364) | -0.002 (1.533) | -0.002 (1.565) | -0.002 (1.646) | -0.002 (1.647) | -0.002 (1.700) |
| Number of mathematics course credits | — | 0.001 (0.114) | — | — | — | — | — |
| 12th grade total extracurricular activities | — | — | -0.0004 (0.056) | — | — | -0.001 (0.121) | — |
| 12th grade hours extracurricular activities | — | — | — | 0.003 (1.360) | — | — | 0.003 (0.580) |
| 12th grade hours of work | — | — | — | | 0.002 (1.692) | 0.002 (1.695) | 0.002 (1.900) |

Sample size 1,831, male high school graduates who entered the labor market directly after high school only.

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## Table 4.6A
## Selected Determinants of Hourly Wage Rates Two Years After High School, 1982 High School Graduates, Women (absolute value t statistics)

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| 12th grade composite test score | .009<br>(2.305) | .009<br>(1.993) | .010<br>(2.349) | .009<br>(2.334) | .010<br>(2.358) |
| Number of mathematics course credits | — | .010<br>(0.429) | — | — | — |
| 12th grade total extracurricular activities | — | — | -.003<br>(0.295) | — | -.004<br>(0.385) |
| 12th grade hours of work | — | — | — | .009<br>(4.149) | .009<br>(4.147) |

Sample size 1,298, female high school graduates who entered the labor market directly after high school only.

## Table 4.6B
## Selected Determinants of Hourly Wage Rates Two Years After High School, 1992 High School Graduates, Women (absolute value t statistics)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| 12th grade mathematics test score | .001<br>(1.0154) | .002<br>(1.402) | .001<br>(1.064) | .001<br>(1.1057) | .001<br>(1.075) | .001<br>(1.076) | .001<br>(0.999) |
| Number of mathematics course credits | — | .009<br>(1.127) | — | — | — | — | — |
| 12th grade total extracurricular activities | — | — | -.002<br>(0.183) | — | — | -.0004<br>(0.050) | — |
| 12th grade hours extracurricular activities | — | — | — | -.001<br>(0.281) | — | — | .0001<br>(0.033) |
| 12th grade hours of work | — | — | — | | .004<br>(2.438) | .004<br>(2.433) | .004<br>(2.443) |

Sample size 1,745, female high school graduates who entered the labor market directly after high school only.

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Table 4.5A shows the estimated coefficients from OLS regression models with the natural logarithm of the hourly wage rate in 1984 (two years after high school) as the dependent variable. All models also include race/ ethnicity dummy variables, family income, number of siblings, a single parent household dummy variable, and region dummies. For more details, see Appendix II.

Absolute value t statistics are shown in parentheses. For these sample sizes, a t statistic greater than 1.645 indicates that the coefficient estimate is statistically significant at the 10% level, and a t statistic of 1.960 indicates that the coefficient estimate is statistically significant at the 5% level.

Table 4.5B shows the estimated coefficients from OLS regression models with the natural logarithm of the hourly wage rate in 1994 (two years after high school) as the dependent variable. All models also include race/ ethnicity dummy variables, family income, number of siblings, a single parent household dummy variable, and region dummies. For more details, see Appendix II.

Absolute value t statistics are shown in parentheses. For these sample sizes, a t statistic greater than 1.645 indicates that the coefficient estimate is statistically significant at the 10% level, and a t statistic of 1.960 indicates that the coefficient estimate is statistically significant at the 5% level.

Table 4.6A shows the estimated coefficients from OLS regression models with the natural logarithm of the hourly wage rate in 1984 (two years after high school) as the dependent variable. All models also include race/ ethnicity dummy variables, family income, number of siblings, a single parent household dummy variable, and region dummies. For more details, see Appendix II.

Absolute value t statistics are shown in parentheses. For these sample sizes, a t statistic greater than 1.645 indicates that the coefficient estimate is statistically significant at the 10% level, and a t statistic of 1.960 indicates that the coefficient estimate is statistically significant at the 5% level.

Table 4.6B shows the estimated coefficients from OLS regression models with the natural logarithm of the hourly wage rate in 1994 (two years after high school) as the dependent variable. All models also include race/ ethnicity dummy variables, family income, number of siblings, a single parent household dummy variable, and region dummies. For more details, see Appendix II.

Absolute value t statistics are shown in parentheses. For these sample sizes, a t statistic greater than 1.645 indicates that the coefficient estimate is statistically significant at the 10% level, and a t statistic of 1.960 indicates that the coefficient estimate is statistically significant at the 5% level.

Turning first to the results for the 1982 cohort, Table 4.5A suggests that academic ability as proxied by a mathematics test score has no impact on early career wages for men. For the 1982 women, Table 4.6A suggests that higher 12th-grade mathematics test scores are associated with higher wages (although it should be noted that this is not the case if the composite HSB test score is used instead of the math score). These results should not be interpreted as meaning that academics do not play a role, rather that they are not critical in early career labor market performance. The results are very similar to those of Murnane et al. (1995) who, using the 1980 HSB senior cohort, found math scores have a statistically significant effect on wages two years after high school for women but not for men.

The effect of adding extracurricular and part-time work activity to this model can be seen in columns (3)-(5). Three things are striking: (1) as these indicators are added to the model, the estimated effect of test score on wages barely changes. This provides some limited evidence that previous results may not have been biased in their restricted focus on academic skills; (2) for this group, participation in extracurricular activities does not yield any positive return in the labor market; and (3) the most important factor among the skill proxies shown in the tables is the extent to which the individual worked prior to entering the labor market. Every additional hour of part-time work in the 12th grade of high school generates a small (.7% in the case of men and .9% in the case of women) but statistically significant wage premium. This result holds for models including the test score only, extracurricular measures only, or measures of both. It is also insensitive to replacing 12th-grade work with 10th-grade work.

A similar pattern of results is suggested by the 1992 cohort results shown in Tables 4.5B and 4.6B. Table 4.5B again shows no evidence that academic skills—as proxied by mathematics test score or curriculum units—have any influence on wages; if anything, there is a *negative* relationship for men in the most complete model (column [7]). (This result is repeated for reading test scores. It also appears to be relatively insensitive to the inclusion of earlier grade level test scores in place of the 12th-grade test score.) Similarly, the effect of adding extracurricular and part-time work activity to this model (columns [3]-[7]) suggests that an individual's work in high school pays off subsequently, although the estimated premia are even smaller than in the 1982 case. Extracurricular activities do not pay off—at least in this sample—even when a more refined measure indicating hours spent on extracurricular activities (rather than simply the number of activities) is used; using 10th-grade extracurricular activities (not shown) also fails to reveal any positive statistically significant effect. Adding extracurricular activity and part-time work measures to the models does not alter the estimated effects of test scores on wages.

There are several reasons to be cautious of these results. First, and most importantly, the measures we have included in the models which we suggest might reasonably be interpreted as proxies for other kinds of skill, and, thus, could reflect many other factors; without more direct measures of generic skills, there is no way to know whether the suggested interpretation is accurate. In particular, as noted earlier, since students choose their skill bundles to some extent, it may be that unobservable factors correlated with extracurricular activities or part-time work bias the estimated coefficients in these statistical models.

Second, it is also important to bear in mind that these results are limited to high school graduates directly entering the labor market, and inferences cannot be made about the payoff to academics, extracurricular activities, and part-time work for other groups. For example, it may be that a high school dropout with a high level of extracurricular participation would be more attractive on the margin to an employer than a dropout with no extracurricular activities. Likewise, there may be a payoff to extracurricular activities for those going on to college given that some institutions may consider these as part of the student's application. As has been suggested elsewhere (e.g., Stern et al., 1997), the short-term payoff in the sub-baccalaureate labor market for this group of high school graduates must be set against the far greater returns they may have achieved had they gone on to postsecondary schooling.

Third, we have only examined wages as a labor market outcome. Although wages are a valid indicator of performance in the market, they are only one. Future studies might explore alternatives in more depth. As noted earlier, we have confined our attention to wages immediately after entering the labor market, which may not be a reliable indication of long-term labor market prospects. We, therefore, re-estimated our statistical models for the HSB sample for which we have earnings information ten years later in 1992 (information is not yet available for the 1992 cohort beyond 1994). Unfortunately, this earnings information is far from ideal since individuals were not asked about hours of work.[32] Log earnings models estimated using the same specifications as those shown for 1984 log wages and reveal the same pattern as those reported. In other words, hours of work in high school are positively associated with wages for both men and women, while extracurricular activities have no payoff; academics (as measured by the mathematics test score), however, are now statistically significant for men but not for women. (Murnane et al. [1995], using data six years after high school graduation, found statistically significant positive effects of the mathematics test score for both men and women.) However, when additional controls are included for total months employed and highest grade of schooling completed by 1992, this latter result on academics disappears. Thus, for this group of high school graduates entering the labor market, we do not find that academics pay off, even if later career earnings

[32] In other words, there is no way to obtain an accurate measure of each individual's wage rate, and labor supply decisions cannot be separated from the wage rate. Consequently, earnings are almost certainly measured with error, which biases upwards the standard errors on the coefficient estimates in the model.

are considered. In contrast, hours worked in high school continue to earn a premium even when a person is ten years into the labor market.

## *Conclusions*

In this chapter, we have argued that the narrow focus on academic skills as important predictors of labor market success could potentially yield misleading statistical results and policy inferences. If individuals possess a bundle of academic and non-academic skills, omission of non-academic skills from regression models of labor market performance may under- or overestimate the importance of academic skills for labor market success. The extent to which this is the case is, of course, an empirical issue and depends on (1) the relationship between academic and non-academic skills, and (2) the relationship between non-academic skills and labor market outcomes.

Ideally, one would investigate these two questions directly. The different dimensions of non-academic skills would be broken down conceptually and valid and reliable measures of these dimensions developed. Unfortunately, this is not the case. Just as with the measurement of academic skills, one is forced to rely on proxies that may to a greater or lesser extent measure the relevant concepts. In large national longitudinal datasets, possible indicators of an individual's non-academic skills are the extent to which students have participated in extracurricular activities and part-time work during high school. Both these arenas at least provide the opportunity to develop a range of skills such as teamwork, communications, responsibility, and so on.

Proceeding on the assumption that extracurricular and part-time work participation should be viewed simultaneously with academics as alternative skill indicators, we used two national data sources to investigate (1) the relationship between academic, extracurricular activities, and part-time work and (2) the extent to which these indicators affect wages two years after high school for those entering the sub-baccalaureate labor market. The analysis reveals that there is a modest positive association between academic and extracurricular activities, and a negative association between hours of part-time work in high school and academics, and, to a lesser extent, between extracurricular activities and hours of part-time work. While no causality should be inferred from these descriptive statistics, they reveal that academic measures alone are very unlikely to adequately capture the multifaceted skills individuals take to the labor market or postsecondary education.

Simple wage regressions for the group of high school graduates who enter the labor market directly after high school suggest (in line with much prior research) that academic indicators have little impact on early career (two years after high school) labor market success. Extracurricular activities also do not appear important for this group.[33] The important skill set seems to come from previous work experience in both 10th and 12th grades—students who worked more during high school earn marginally more once they enter the labor market after high school. The inclusion of these additional skill indicators, however, does not appear to change the estimates of the effects of academic skills when these are included alone. If this result were to withstand further sensitivity analyses, it would imply that previous research that has omitted measures of non-academic skills might not have suffered from a large degree of bias. Of course, this statistical result does not imply that the inferences made in prior studies about the importance of academics is correct. Our results suggest that, at least for the group of individuals directly entering the sub-baccalaureate labor market, there is a bigger payoff to work experience in high school than academic ability or coursetaking. This could imply a very different set of school-sponsored activities such as work-based learning for non-college-bound students.[34]

Without direct measures of skills and a full understanding of how extracurricular and part-time work experiences enhance an individual's skills, we can only speculate that the measures we have used contain useful information about skills. It would appear that employers do not systematically reward academic preparation for the kinds of jobs our samples of high school graduates are undertaking[35]; rather, they attach a premium to the extent to which individuals have worked while in high school. Whether this reflects a true return to the skills learned in part-time high school jobs or the use of this indicator as a signal of some other trait such as motivation is hard to tell from these data; however, it appears that some useful information is contained in these measures.

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[33] Given the very large differences in participation in extracurricular activities between those who go on to a four- or two-year college, and other groups (Tables 4.4A and 4.4B), it seems likely that extracurricular activities may play a larger role in determining entry to college, although this is speculative without further multivariate analyses.

[34] Further investigation would be needed to draw similar inferences for college-bound students. Also, any policy shift such as that suggested here would obviously need to be based on a full accounting of other (including social) costs and benefits, not just on the result obtained here.

[35] Students entering the labor market directly after high school in our samples appear to go into a wide range of jobs. For example, for the 1992 cohort, 15-20% went into clerical positions, 10% were laborers, about 15% went into skilled trades/craft jobs, 10% were in sales, and 15-20% were in service occupations. Beyond self-reported categorizations of this sort, little information is collected in such data about the tasks performed and responsibilities an individual has at work.

CHAPTER 5

# Summary and Discussion

This exploratory study examined relationships between academic skills, non-academic skills, and work. Educators, employers, and policymakers are interested in academic skills for several reasons; chief among them is a concern that changes in work require different preparation in school if youth are to make a successful transition to employment. This study examined academic skill along three strands of inquiry. A review of the literature highlighted some important theoretical and methodological approaches to the study of academic skills and how these different perspectives can sometimes produce conflicting recommendations for policy or practice. The positivist perspective conceives of skills as unitary, measurable traits of individuals and holds strong assumptions about a person's ability to transfer skills from one context to another. The situative perspective assumes that skills are larger than the behavior and cognitive processes of a single person. Rather, individuals act in social systems that help determine skill requirements, distribution of skills in the work setting, and other important factors. Direct transfer of skills from one setting to another is rare. Neither perspective, nor variations on these two dominant paradigms, provides a complete picture of the place of skills in work.

While sharing the view that skilled behavior is multidimensional, different perspectives on skills at work are covered in Chapters 3 and 4. The study in Chapter 3 takes a situative perspective to describe academic skills observed in seven technical jobs. Although data from these jobs does not generalize to all technical work, the study provides a rich picture of skills in context, especially the relationships between academic skills and work technology. Academics are important in all the technical job studies and range from fairly basic mathematics to complex trigonometry. Some jobs clearly identify with a single discipline (e.g., trigonometry for surveyors, electronics for traffic signal technicians) while technology drives the skill requirements in others (as with test and equipment technicians). The language that workers use to discuss academic skill does not necessarily correspond with the topics or subject areas defined in the school curricula. Managers and workers seem to have a common understanding about academic skill requirements. This last finding departs from our earlier studies of generic skills or work-related attitudes in which there was less agreement between the two groups on skill needs (Stasz et al., 1996).

Chapter 4 reports on an analysis of longitudinal survey data to explore relationships between non-academic and academic skills and labor market performance. This analysis extends the usual positivist approach by taking a multivariate view and considering academic and non-academic skills simultaneously. It suggests that in the absence of well-developed measures of non-academic skills, it may be appropriate to view students' participation in extracurricular activities and part-time work while in high school as proxies for these skills. We find a modest positive association between academic and extracurricular activities, and, to a lesser extent, between extracurricular participation and hours of part-time work. These results suggest that academics alone will not capture the range of skills that individuals take to the labor market. Simple wage regressions confirm earlier research in showing that academic indicators have little impact on earnings in the early part of high school graduates' careers. For this group, extracurricular activities and academics are less important than work experience in predicting early labor market success.

The two studies have different kinds of implications for practice and policy due largely to the basic conception of skills that each endorses. The study of academics in technical jobs provides details about specific skills in work and, thus, speaks to practitioners' concerns about what and how to teach. First, this analysis and several studies cited in the literature review demonstrate the extent to which academic skill requirements are contextually bound. They may be closely linked to a discipline (as in electronics) or to specific technology applications. Academic skills are always used in applied contexts—technicians, for example, do algebra for a purpose, to solve a problem, not just for the sake of solving algebra problems. The discourse about academic skills differs between work and school: In work settings, academics are so intertwined with context that they may not be discussed in formal terms; therefore, the academic skills are in some sense "hidden" in the work activity. A cursory look at that activity may not reveal the academic skills required, nor will questions about academic skills posed to workers themselves. The challenge for research is to reveal both the obvious and the hidden skills in a manner that speaks to educators. In addition, researchers can also continue work to better define skills and knowledge, to help reduce the overlap among different skill frameworks in order to arrive at a more consistent terminology.

The situated nature of academics poses a dilemma for educators if developing transferable knowledge is an important goal of formal education. Instead of viewing academic knowledge as archetypal, it may be preferable to accept that knowledge is transformed by application in different kinds of social and cultural practices. These practices give academics meaning and may have elements—mathematics, scientific principles—which are embedded in tasks. For educators, the challenge is to design learning tasks or environments that primarily reflect the potential uses for the knowledge being taught. Learning tasks must be "authentic"—coherent, meaningful, and purposeful (e.g., Brown et al., 1989). The situativeness of knowledge has strong implications for instructional practice which have been clearly spelled out, for example in the writings by Collins et al. (1989) and others on cognitive apprenticeship. Similarly, educators and researchers have embraced the idea that there is special value in contextualized, situated, or experiential learning. While these ideas are finding their way into teaching practices, there is still much conceptual and practical work to be done to transform instructional practices. Even as practice changes, educators face significant obstacles, such as standardized tests, that reflect the abstract, transferable view of academic knowledge. The tensions discussed in Chapter 2, then, are not just scholarly debates, but carry through to everyday practice in schools.

A second important finding from our study is that technical work may regularly utilize high-level mathematics and scientific knowledge. Of the seven occupations we examined, five required algebra or higher mathematics and several required specific scientific knowledge. These results concur with Murnane and Levy (1996) by supporting that it is important for students to have "the ability to do math at the ninth grade level or higher." For most of the jobs we examined, math requirements certainly exceeded 9th-grade algebra.

A third finding concerns the role of technology in defining academic skill requirements and implications for technology education. It is impossible to discuss skills in these jobs without referring to technology. The technologies present in these work sites make use of other disciplines, including mathematics, science, and communication. Technology can shape the nature of the skills needed in several respects. Obviously, workers need to learn how to operate and use the technology and to keep up with technology changes; however, technology can also affect academic skill needs in different ways. Technology may make some academic skills obsolete; the extensive use of calculators is an obvious example. Alternatively, technology advances may significantly change the academic skill demands, as in the case of traffic signal technicians in which digital systems have replaced electromechanical devices.

Historically, technology education has been a core element in vocational education; vocational courses taught in high schools help develop the skills associated with particular occupational technologies (Raizen et al., 1995). As taught in vocational coursework or training, technology education can take different forms. It can emphasize practices firmly fixed in the craft-based tradition, or it can focus on current or high-tech industrial practices. It may focus on the manual skills needed for operating a piece of equipment, or it may focus on cognitive competencies by drawing on systems theory, for example. In either case, ties to the academic curricula or to the academic skills embedded in technology need to be made explicit. Given the rapid technological change found in many technical occupations, the tight relationship between skills and context, and the need to understand why a particular technology application behaves the way it does, instruction that emphasizes manual skills may be sorely inadequate.

Recent attention to improving technology education emphasizes teaching in ways that involve students in designing, building, and evaluating artifacts and in applying academic skills, particularly from mathematics and science. In this way, technology education can unite cognitive activity with practical activity, as is seen in many of the work examples presented in Chapter 3. Examples of teaching technology in this manner are increasingly available and provide a rich resource for academic and vocational teachers (e.g., Raizen et al., 1995; Steinberg, 1998; Vickers, 1998).

The analysis in Chapter 4 has less to say about specific skills, since the proxies used for academic or non-academic skills in these analyses do not measure skills with much precision. Work experience, for example, can provide opportunities to develop a variety of non-cognitive skills; similarly, measures of academic coursework represent a wide variety of these skills. There are some similar patterns across both types of analyses, however. Both suggest some value-added to considering skills as multivariate, although further empirical studies are needed to sort out finer relationships among skills and various outcomes.

These analyses also have something to say about how employers value academic skills. The case study analysis in Chapter 3 suggests that traditional measurement of academic skills, for example, through standardized tests or coursetaking patterns, may provide reliable information for employers about job incumbents' academic background. Although we cannot measure this relationship directly from the case study data, we see several indicators of the usefulness of traditional measures. Employers use educational attainment in hiring decisions and can describe differences between employers with different educational backgrounds (e.g., high school vs. community college degree holders). They may also test job applicants to ensure that they have specific knowledge (e.g., survey inspectors).

The analysis in Chapter 4 reveals that for high school graduates entering the labor market, employers are much more likely to reward part-time work experience than academics or extracurricular participation. Similarly, the case study data (Chapter 3) indicate that in addition to looking at various measures of academic skill proficiency, employers value experience. They consider experience with relevant technologies in hiring decisions and may also reward individuals who possess special expertise with very advanced technologies. The findings from both analyses that employers value experience is consistent with evidence from employer surveys done by NCEQW cited in Chapter 2.

The case study data depart from the Chapter 4 analysis (and from employer survey data) in suggesting that employers may also value academic background in some technical occupations in the sub-baccalaureate labor market, many of which require some education after high school. This difference may be due to the differences in the sample. The Chapter 4 analyses reports on high school graduates two years after graduation, while the study participants discussed in Chapter 3 are further along in their careers. In addition, the Chapter 4 analysis does not specify the types of jobs that students enter after high school. It may be that academics play some larger role, relative to experience, in wage determination for the subset of students who go on to work in technical fields. Without better information about the types of jobs and more reliable data on non-academic skills from a larger number of individuals, it is difficult to sort out the relative importance of education versus experience in rewarding labor market performance.

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APPENDIX I

# Workplace Skills in Practice

Our study examined seven jobs in detail: (1) traffic signal technicians working in the Traffic Management agency, (2) licensed vocational nurses (LVNs) and (3) home health aides (HHAs) in the Health Agency, (4) test cell associates and (5) equipment technicians in the Microprocessor Manufacturing firm, and (6) construction inspectors and (7) survey inspectors at the Transportation Agency. The following scenarios describe these jobs in more detail and are based on data gathered from observations, interviews, and documents collected at the sites. They are intended to convey a picture of the job as situated in the larger contexts of work and organization.

## *Managing Traffic*

From all appearances, the maintenance yard of the Department of Public Works seems similar to yards in any other medium-sized city in the United States—men and women in brown and orange uniforms walk among maintenance sheds labeled as sanitation, street maintenance, electrical, and carpentry shops. Sanitation vehicles, a variety of pickup trucks, and a few covered electric carts sit in the lot. A mix of office personnel and line staff stand in the middle of the yard chatting amiably while going through stretching exercises designed to reduce back injuries.

This image changes almost immediately, however, when one enters the offices of the traffic signal maintenance unit. The first room one sees on entering this shed is the "Traffic Control Room." Through the glass panel in the door, one can see the computers, video monitors, and communications equipment that are crowded into the small room—a mix of high technology that seems out of place in this setting. There is only one reason why this traffic signal unit has this technology—Sam Burns, the director of the unit.

Sam, who is in his mid-50s, is dressed in a button-down shirt with a faded tie. Both a beeper and a walkie-talkie are attached to his belt. He is happy to offer interested parties a short tour of this unique facility, a "traffic surveillance" system that enables him to monitor most of the intersections in the downtown area. Two large monitors display video images of traffic movement along the main roadway through town. A computer terminal in another corner shows activity at one intersection as the signals go through their "phases," controlling traffic flows and pedestrian crossing patterns in four directions. These signals are sent to the control room from microprocessor-based "controllers" located at each intersection. These units not only control the timing of the lights at the intersection, but also communicate with the central control room via a network of coaxial and fiberoptic cables that connect almost all the intersections in the downtown area of the city.

Rapid changes in information and communications technology have very much led to a silent revolution under and above the streets, fundamentally changing the demands facing traffic signal technicians in this unit. Sam switches the video display to show another intersection, at which magnetic signal "loops" embedded in the roadway have been replaced by programmable video detectors that change signals when vehicles pull up to the intersection. The traffic signal unit is working with manufacturers as a "beta" test site for this new technology, which has been installed at two intersections in the city. Sam proudly explains the even newer technology that the unit has begun using: miniature microwave transmitters to communicate among controllers in the network, cellular communications to download "timing patterns" from the central computer system to controllers in the field, and even radar and sonar devices to monitor the speed and density of traffic flow.

The differences between this technological wonderland and the day-to-day reality of traffic signal maintenance are unveiled almost immediately after one leaves the signal control room and enters the "shop." Dusty shelves piled high with spare red, yellow, and green traffic signal gels, pedestrian crossing buttons, wiring harnesses, and other hardware reach to the ceiling. A large four-way "auto head" runs through red, yellow, and green phases from its perch on a mounting pole in the middle of the floor. Two new aluminum "cabinets" containing all the electronics used at an intersection stand nearby, running through tests that ensure their proper operation before they are placed in the field. Two "signal techs" sit at work benches, a variety of electronic units open before them as they work on testing and repairing damaged devices. Units too old or too damaged to be repaired sit on shelves atop these work areas. One of the techs says "you never know when you might be able to use something" in these units. The dust covering this pile of units indicates that they have not found a use for these parts in a long time.

Out in the field, Mark, an experienced technician, notes a head that has been knocked out of alignment. He points out that this is one intersection through which trucks pass on their way to the harbor, and it has only eight-foot lanes that are difficult for big trucks to negotiate. As a result, trucks will bang into the signals hanging at the corner, forcing him to return to this intersection many times to repair this signal. This problem could be averted by a slightly wider lane, but he feels that the engineers are not going to listen to him.

Mark pulls the truck up to the corner under the misaligned light, and turns on the yellow warning flashers. He sets out six orange traffic cones behind and next to the truck. He pulls on his chest harness and removes several tools from the tool bin on the right side of the truck—a socket wrench; some light bulbs; and a large, specialized wrench. He places the bulbs and tools in the bottom of the bucket attached to a boom on the back of the truck, and climbs aboard. After attaching a safety line, he moves the boom to a spot adjacent to the signal using the controls located on the end of the boom arm.

Mark first turns the light to its proper orientation. He turns the wing nuts on the edge of the cover, and opens up the top and bottom lights. He cleans the lens and reflectors within the light and changes the bulbs. Using his hands, he bends the twisted sheet metal "backplate" on the signal back into a reasonably straight shape. Using the special wrench, he finally tightens the top and bottom bolts on the light. Mark moves the boom next to the other auto head on the pole and repeats the cleaning and bulb changing procedure.

This is a very busy intersection near the entry to the harbor. The two roads have six and five lanes, respectively. Traffic moves by at almost highway speeds, and the majority of vehicles seem to be medium-sized and large trucks. The whoosh of buses, trucks, and honking horns is overwhelming. It is loud, dusty, and a very gritty corner. The smells from the harbor, the oil refinery, and a nearby garbage-burning power plant are very strong, and seem remote from the high-tech wizardry we saw back at the shop.

## *Caring for Patients at Home*

Irene Simmons walks up to the door on the first floor of a small apartment building and rings the bell. After a few moments, a frail voice calls, "Irene, is that you?" and opens the door to let us in. As an LVN who works for a home health care agency in Los Angeles, Irene has visited this patient once or twice a week since his discharge from the hospital two months ago. Even without meeting her, however, one would immediately know that Irene is a nurse, as much from her terse but nurturing manner as from the white coat, identification badge, and stethoscope she wears. The patient is in his late 60s and has been diagnosed with end-stage AIDS. His home is cluttered, somewhat dark, and stuffy. Near his bed in the living room sit a number of small tables piled high with pill boxes, tissue dispensers, blankets, and medical supplies. A television plays loudly in the corner—the patient makes a point of telling us that he watches the news, never the soaps. While he is quite coherent, he is clearly a fragile, ailing man.

Irene visits this patient to monitor his condition. She begins by asking him a series of questions about his appetite, drinking, bowel movements, urination, and sleeping patterns. She helps him over to a scale to measure his weight, supporting him so he will not lose his balance as he steps up onto the machine. She compliments him on having continued to gain weight—his inability to do so is the primary reason the nursing case manager, Kathy Carlson, has had them continue visits on such a regular basis. Irene also uses a blood pressure cuff to check the patient's blood pressure, makes certain that his pill boxes are filled for each day in the next two weeks, and tells him that she is sorry to see an ashtray filled with cigarette butts in his living room—smoking is very bad for a person in his condition. After washing her hands, Irene thanks the patient and reminds him that she will be returning early next week for another visit.

When we go to her car, Irene says it is usually filled with files and nursing supplies that she needs in the field. She normally spends much of her day alone driving around the city. As she drives to the second of five homes she is scheduled to visit this day, her beeper goes off. While she would like to have a portable phone that would allow her to respond immediately to her supervisor when she beeps, the home health agency does not provide them, and she may not want to carry such a valuable item into some of the neighborhoods she has to visit. Instead, she will use the phone at the next patient's home.

Another staff person from the home health agency has arrived at this home ten minutes earlier. Sue Perkins is a home health aide (HHA) whose main responsibility is bathing patients. The patient is already in her bathrobe and ready for her shower, so Irene tells Sue she will wait until they are done and use the time to call Kathy and get a start on some of her paperwork ("charting"). Irene notes that it is not uncommon for her to run into other members of the "treatment team" who work with these patients. When a patient is referred to the home care agency, a registered nurse (RN) conducts an assessment visit, identifying needed services that must be provided to each patient. A single case can have four or more service providers assigned, including RNs; LVNs; HHAs; social workers; and physical, occupational, or speech therapists. If a service is needed and the agency has no staff available to provide the service, the case manager will arrange with the intake unit to have an outside contract agency provide that service.

While Irene makes her calls, Sue has helped the patient move into the bathroom. The patient is in her early 70s, has very pronounced surgical scars on her chest, and has just had her left leg amputated below the knee. After placing a bath bench in the shower and making certain it is stable, Sue turns the water on and warms the seat. The patient moves next to the bench and, with Sue's assistance, lifts herself out of the chair and onto the bench. Sue notes that while it can be difficult to have to lift and move some patients, this patient has been well-trained in moving in and out of her chair by her physical therapist. Beyond bathing the patient, Sue takes the opportunity in the shower to lead her through a series of range-of-motion exercises and also checks the patient thoroughly for any marks or redness on her skin. Such marks can be signs of injury or even abuse. Sue will report any new marks to her case supervisor.

After Sue finishes helping the patient dress, she says good-bye and leaves. Irene moves quickly through her check-up of the patient, asking the same series of questions she asked at the first home and checking blood pressure. She also draws a small blood sample, which will be tested by the agency lab to ensure that the patient's medication is appropriate. The sample is placed in a small icebox to keep it cool until it reaches the lab. After checking the patient's pill box, she says good-bye and departs to the third patient's house, which is just a few blocks away.

The home health agency for which Irene works is reorganizing in ways intended to provide quality care at competitive prices. Like other health agencies around the country, it is doing so, in part, by shortening hospital stays for patients and increasing home health care. This change affects not only the training needs of home health care workers like Irene and Sue, but also the balance and distribution of skills for the patient care team, which includes doctors, nurses, pharmacists, therapists, and other health professionals.

## *Manufacturing Electronic Components*

The Microprocessor Manufacturing Corporation (MPM) is a mid-sized, specialized manufacturer of cutting-edge microchips. A family-owned firm that has been involved in the construction of electronic components used in military or space applications since the 1940s, MPM expects global sales to approach $1 billion by the end of this century. To reach this goal, the firm built factories and distribution centers in the United States, Mexico, Europe, and Asia. More recently, they began implementing new approaches to structuring work in some of their units, approaches that reflect many of the latest management practices reported almost daily in the business press.

One unit that has received a great deal of attention in MPM is the Z1 Test Cell, a quality assurance unit that performs final testing and quality certification on some of the most complex chips MPM produces. The cell's work area is part of a larger work area crowded with testing and finishing equipment serving all cells responsible for final production of the most complex military and space-level microchips. Everyone in this "clean room" wears blue anti-static smocks and hair nets to protect the sensitive chips from static electric charges that could be damaging—failure of one chip could disable a multimillion-dollar satellite or piece of military equipment.

The Z1 cell team consists of four members: two experienced technicians (Ng and Roger) and two relative newcomers to MPM (Tom and Prat). This cell has largely taken the lead in implementing the new management practices that have been put in place in MPM over the last year. Control charts showing statistical process control measures such as cycle time, throughput, work in progress, time in queue, and downtime cover a corkboard in the cell. One-third of the space available in this work area is empty, following a recent redesign of the layout of the work area that identified the additional space as a factor in elevated cycle times. When one asks any member of the team who the team leader is, he responds that decisions are made as a team and that no individual holds sway; however, even a small amount of time spent in the unit reveals that these new practices may not have taken hold quite as deeply as it seems. Team members do not understand all the control charts that are posted. When the supervisor needs something to be done, he will immediately approach Ng with the problem, and rely on Ng to lead the team through the development of a solution to the problem.

On a day-to-day basis, however, this is not a common event; the work is very steady and often repetitive. Each member of the cell works independently, running different batches of chips through a sequence of tests specified in a "lot traveler" form. While the test sequences do vary by type of chip and customer demands set in contracts, they generally follow a similar flow. Once the chips are drawn from the stockroom, they are mounted on aluminum "test boards" and run through high- and low-temperature cycling tests. All aspects of their operation are then tested on the "DAC," an electronics testing machine that is so complex that it requires its own mini-computer. Chips are then run through tests of the "source" (the output side of the chip) and "gate" (the input side of the chip) to ensure they can handle the voltages for which they are rated. Before chips run another cycle through the DAC, some lots (especially those to be used in space satellites) are run through a centrifuge test to see if they can handle physical stresses, and an x-ray test to check for minute fractures. Despite these demanding tests, failure rates exceeding 2% were rare.

While the members of the test cell have stronger technical backgrounds than many production workers in this unit, these differences only emerge in subtle situations. For example, one of the newer technicians (Tom) had just been trained to use a PIND tester—a piece of test equipment that was to be transferred to the new unit the following week. While Ng had never used the equipment before, he was surprised at how long it was taking Tom to learn the equipment. Tom reported that he had, in fact, learned how to use the equipment in about one hour, but that he had been trying to run a batch of chips through the tests and that these tests were very long and very labor-intensive—each chip had to run through the PIND tester five times, one chip at a time. This did not sound right to Ng, who checked the engineer's manual to see if this was the proper test procedure. It was not. Chips only had to go through the test one time, unless the failure rate for a lot exceeded 2%. For Ng, solving these problems was one of the most enjoyable aspects of his job.

In another department at MPM, technicians are working on research and development of new chip processing technology. In this area, the men responsible for repair and maintenance of the machines are constantly on call to troubleshoot and repair machines that are down. As in other parts of the company, downtime can cost the company in terms of lost production, which places pressure on the technicians to perform rapid, yet thorough work. In addition, the chemicals and machinery used in this area can be quite dangerous—techs literally have the lives of other workers in their hands.

The team of technicians consists of six men who work two at a time, 24 hours a day. The senior equipment technician, Bob, has been at MPM for ten years, having come directly from high school. Since coming to MPM, he has completed an A.S. in Electrical Engineering and a B.S. in Manufacturing Engineering on his own time. He generally works independently, first checking the semiconductor productivity network (SPN) to see which machines are down, and then traveling around the "fab" (the room that houses the manufacturing equipment) to work on various pieces of equipment. He is very efficient and deliberate in his actions; it is clear that he knows his machines and feels confident. At the same time, he says he likes his job because there is always something new to learn since the technology is constantly changing. The very nature of his job means that he is continually faced with new problems to solve when machines go down.

Bob also likes the technician job because of the diversity of responsibilities involved, from performing equipment modifications and upgrades and cleaning and rebuilding parts, to designing out errors from the machines. His job also involves developing operating procedures for equipment, completing paperwork, and updating the status of his work on the computer through the SPN. In addition, since Bob has a great deal of experience at MPM, he trains the new technicians. Using a combination of lecturing, coaching, and hands-on demonstrations, he helps bring new and less expert employees up to speed.

Bob keeps in constant communication with the staff operating the machines. They all make quite an image as they move about the lab completely decked out in blue smocks, hoods, gloves, surgical masks, and boots (which are necessary to keep a completely sterile environment). The operators approach Bob whenever machines are down or they want him to delay work on a machine. In addition, the statistical processing information that the operators provide to Bob helps him recognize and diagnose problems with the equipment and determine repairs. At lunch, Bob joins the operators in the break room. All of the operators are female, while the technicians are male. They spend the lunch hour chatting about various personal and work issues such as the new work schedule being implemented by management so that the plant can operate 24 hours a day, seven days a week. All but three of the 20 team members have volunteered to change their schedules. They will continue to get the same pay, but will only have to work 70 hours every two-week period instead of the traditional 80 hours.

Bob does not seem concerned about the upcoming change in schedule. He takes it in stride, just as he takes the rest of his job. His accommodating attitude helps him not only deal with, but enjoy the demands of his job.

## *Building a Transportation System*

There may well be no more visible public project in Los Angeles than one that is going on underground: construction of a new subway system that will, over the next 30 years, cost an estimated $180 billion. With the unsteady southern California economy, this project has received substantial attention not only for its ability to meet the region's transportation needs, but in its role as a potential economic engine. It has also been subject to enormous attention from political actors and members of the media, who have frequently emphasized cost overruns, design flaws, and questions regarding the quality of its construction.

The size, scope, and complexity of the Los Angeles subway system requires meticulous planning and substantial oversight. While planning is the responsibility of a regional Transportation Agency (TA), three international construction firms are responsible for actually building the system. Between the TA and the contractors sit the project's contract managers: one engineering firm for each of the "lines" of the system, which are responsible for quality assurance by ensuring that the construction firms and thousands of subcontractors building the subway do so in strict accord with contract requirements. In essence, their goal is to "make sure the TA gets exactly what it is paying for." On a day-to-day basis, this work on the subway "line" falls to construction inspectors, who spend each day on the construction site.

Ten teams of inspectors are assigned to different sites snaking along the TA's Yellow Line construction project. These teams are responsible for making certain that all aspects of the construction process—excavating tunnels and stations; pouring concrete walls; installing electrical, plumbing, and communications systems; laying track; and restoring streets after construction—are completed properly. The breadth of these tasks requires inspection teams made up of highly experienced staff members, each of whom has a different specialization. These areas of expertise are reflected in the makeup of Team One, which is currently based near the station that is under construction at the intersection of Main Street and Fifth Avenue near downtown Los Angeles. The four members of the team have surprisingly similar backgrounds—all have pursued some college education (engineering, architecture, or design), but only one has a degree. All have extensive experience in construction, and most have worked on large projects before—freeway construction, mining projects, and international construction. Each has a unique specialty: Sidney, the lead inspector, has a background in design and as a manager of his family's construction company; Paul is a communications and electrical specialist; Andy's expertise is in metallurgy and excavation; and Rex specializes in mining and mechanical units.

Team One's offices are crowded and "functional"—the four inspectors have their drafting desks right up against one another. Each desk is layered with plans, production schedules, and progress reports. Two large blueprint stands and a tall metal rack (piled with hard hats, flashlights, safety glasses, and several new red "safety" vests) stand against the walls. No computers are in evidence. Walls are papered with plans of the station under construction nearby, including cross-sectional maps of the station without walls, a map of the tunnel, a construction schedule, and a milestone chart. A small sign over one of the drafting tables says "Arguing with an inspector is like wrestling with a pig in the mud. After a while, you realize the pig enjoys it."

The construction site is located across the street. Surrounded by a chain link fence, the site stretches a full city block and goes down more than four stories underground. While a compressor and cranes operate at ground level, the site is surprisingly quiet—traffic has been diverted around this block, creating an oasis of calm in the heart of the city. This situation has generated vehement complaints from local merchants, who fear losing their businesses before the construction is completed. Sidney has suggested that everyone in the team do as much shopping as they can at these stores, as a small gesture to help the owners. One enters the work area via an ill-shapen wooden ladder that allows one to climb ten feet down onto the roof of the "station." At this point, there are no internal walls in place in the station, and one can only imagine where the tracks will run and where the elevators, staircases, and token booths will be placed. The most important work site today is on the third level down in the structure, where crews are working rapidly trying to build a concrete wall. It is cold, wet, and dusty in the completely enclosed space; the only light illumination comes from several lights powered by two small, noisy generators. Approximately 30 men (there are no women working in this area) are working on the wall.

Electrical workers are moving feverishly around the work space: two workers are "tied off"—30 feet above the floor—pulling six-inch-thick cables of wires through holes atop the wall, while six other electricians work below them trying to pull the cables through a thick plastic cover. The foreman of the electricians' crew is clearly very nervous. Paul comments that he is an experienced electrician who has only recently been named foreman. His crew has been on the site since two a.m., struggling for seven hours now to get this cable installed. A carpentry crew that came to the site at four a.m. has been held up in its work by these delays, and they are starting to work around the electricians because another crew has been scheduled to begin pouring cement for the wall in two hours. The carpentry foreman called to Paul as soon as he saw him, complaining loudly about the delays—delays mean overtime; overtime means higher costs; and higher costs can mean the jobs of the foreman and his crew, even if they were unavoidable. Paul tells the foreman that he will explain the delays in his report.

Paul sees the situation unfolding at the wall now as potentially problematic, and he wants to avoid any mistakes that might create big expenses later. Paul approaches the nervous electrical foreman and asks him whether he thinks it is a problem that the cable is so twisted; the foreman recognizes the problem and fixes it. Later, Paul comments that, while many people have the technical knowledge to do this job, effective inspectors must plan ahead and do their homework to avoid problems and have the ability to maintain professional relationships and effective communications with others on the site.

As he moves out of the station, Paul gives a friendly wave to a crew of plumbers installing a pump in a narrow crawl space above the roof of the station. Once he climbs out of the station, he calls Rex on his walkie-talkie and tells him that the plumbing crew is installing the pump. Rex thanks him and tells him he will be right over to check the installation and to make certain there has been no damage to the rebar in the roof. Paul comments that, while each inspector works independently with different specialties and different assignments on the site, they are a team in the sense that "everyone watches out for each other." As Paul leaves the site, he walks over to a member of the traffic control crew and asks him to replace a stop sign across the street that had been graffitied over—not only is it a potential safety hazard, but it is an eyesore that may lead to complaints from neighborhood merchants.

Across town, another group of inspectors works in an almost completely different setting, using very different techniques. Here, the inspectors are involved in some of the last stages of the construction of the Orange Line, an elevated and surface rail line that will, when it opens in another six months, serve residents of the areas south and east of downtown Los Angeles. The rail line is almost completely finished; tracks have been laid, staircases installed, and electrical hookups completed. Other than the three-person survey crew working its way along the length of the track, the only other workers at the site are doing some final installation of electric fixtures, putting up signs and finishing the painting of handrails and a few other features. There is an unhurried, quiet feeling to the work site.

The crew stand around their van, sipping coffee from steel thermos bottles. The van is very much an "office on wheels" for the crew; it has room to seat four, with a small drafting table built from plywood and two-by-fours attached to one wall. A plywood rack provides a place to hold blueprints and maps. The back of the van is piled high with equipment and tool boxes that are needed in any work site. The crew chief sits at the drafting table, reviewing plans for the station and filling in a series of "elevation sheets" that reveal the position the track is supposed to have according to specifications. To determine these positions, the chief must use his "most important tool"—a hand calculator that he has previously input with special programs that allow him to determine the proper placement of the rails to a one-eighth-inch tolerance, even when they have turns and subtle twists. These twists, which the chief calls "spirals," mean the rails actually form a parabola, even though it may not be visible to the naked eye. Without these spirals, though, the trains would not be able to negotiate turns safely.

The crew's job, in effect, is to make certain that the tracks are in exact placement according to plans. This is essentially the final quality control check and certification that the construction of the line was done properly. The positions of the track are measured in relation to "control points" that have previously been set at a number of fixed, unchanging locations. In addition to the spiraling of the rails, this site has an additional complication for the crew: the rails sit on elevated platforms more than 40 feet high. This requires a series of calculations to move from three control points on the ground at the nearest traffic intersection over and up to the rail line. The chief comments that these calculations force surveyors to develop an "algebraic mind" and the ability to place objects from two-dimensional maps and drawings into the three-dimensional world. While the chief works for 45 minutes on the next set of calculations, the members of the crew begin unloading the equipment they will need for today's work.

Three elements make up the set of equipment used by a survey team. The main tool is an electronic distance measurement (EDM) machine, which the crew calls a "gun." Mounted on a tripod, the EDM contains sophisticated electronic systems and a laser, permitting immediate calculation of elevations and distances for objects that are "shot" by the operator. The "gun" must be placed in a precise location that has been carefully established in relation to the ground control points, while measurements are made in relation to a "traverse line"—a straight line established between two control points that are in known locations. The second element in the survey equipment is the "back site"—a reflective prism sitting atop a tripod over the second point on the traverse line that provides the base off of which any objects within the 500-foot range of the EDM machine can be precisely measured. Measurements are made using the third element in the survey system—a "linker rod" that is placed on each object that is to be measured and sighted through the EDM's viewfinder. The laser in the EDM bounces off the rod and back to the machine, where the electronic systems in the machine calculate the distance to the object. These measures are compared against the figures calculated by the chief to determine if the objects (here, the rails) are in proper position. As noted above, a deviation of more than one-eighth inch will be considered outside of specifications on this job and will require the contractor to correct the deficiency.

As the crew moves to the elevated train station, each member of the team assumes his position. The "chain man" uses a "plumb bob" to set the back site directly above a "PK" nail that has been driven into the concrete rail bed at a carefully determined temporary control point. The "instrument man" does the same with the EDM machine, but is unable to correct the alignment between the machine and the back site without the help of the chief—he has only been working as an instrument man for three months and has not yet mastered many aspects of the operation of this complex machine. Once the instrument is in place, the chief calls to the chain man over the walkie-talkie, directing him to the first site to be measured. The chain man tries to predict where the chief might next send him, and thus only has to take a few steps to find the proper placement. He places the base of the linker rod on the marked spot, pulls a level from his tool belt, and uses it to ensure that the rod is directly perpendicular to the spot. The chain man comments that many of the tools in his belt are homemade—surveying is such a specialized field that it has become a tradition that surveyors will make many tools that are not commercially available, just as they must often study on their own to learn how to operate new equipment or to solve problems they have never faced before. When he calls "mark" over the radio, the instrument man tells the chief what the reading is. The chief marks the reading down and enters any variation from specifications in the elevation sheet. When the chief is satisfied, he orders the chain man to move to the next spot, and the cycle repeats itself until the 500-foot section of track on both rail lines has been checked.

During a break later that afternoon, the chief begins to talk about the "global positioning system" (GPS)—a surveying system that uses a network of space-based satellites to fix on any object on the surface of the planet. While GPS is not yet accurate enough to perform the kind of precision work the crew is doing on the Orange Line, the chief believes it will eventually replace much of the surveying technology currently in use.

APPENDIX II

# Data Samples and Variable Definitions

In this appendix, we outline the data that were used to generate the tabulations contained in the text.

## *High School and Beyond (HSB)*

In 1980, NCES sampled over 30,000 sophomores and 28,000 seniors from high schools across the nation for its High School and Beyond survey. Data were collected from students and their parents, teachers, high school guidance counselors, and principals, as well as from high school transcripts. Cognitive tests were administered during the base year (1980) and first follow up (1982). Sophomores and seniors were surveyed every two years through 1986, and the 1980 sophomore cohort was also surveyed in 1992, ten years after graduation from high school.

For this study, three samples were created using 1980 sophomore cohort data from the HSB:92 fourth follow-up restricted release data file:

1. Education Status in 1982
2. Ability Quartile
3. Education or Labor Market Status in 1984

### Samples

*Education Status in 1982*

This sample was categorized into four mutually exclusive sections: (1) high school graduate in 1982, including individuals who received a high school diploma in 1982 and excluding late graduates, early graduates, and anyone born before 1962; (2) dropouts, including individuals without a high school diploma, GED, or certificate by the end of 1982; (3) GED, including individuals that obtained a GED or certificate by the end of 1982; and (4) other category, including individuals born before 1962, early graduates, and missing values.

*Ability Quartile*

The ability quartile sample categorizes individuals by quartile ability in 1982 (their senior year). Ability is measured by the student's composite test score for the 1982 tests in vocabulary, reading, and mathematics. The vocabulary test (21 items, 7 minutes) used a synonym format. The reading comprehension test (20 items, 15 minutes) consisted of short passages, followed by comprehension questions and a few analysis and interpretation items. The mathematics test (38 items, 21 minutes) required students to determine which of two quantities was greater, whether they were equal, or whether there was insufficient data to answer the question.

Students also completed tests in science, writing, and civics education; however, these subject tests are not included in the composite test score.

*Education or Labor Market Status in 1984*

This sample categorized individuals into five mutually exclusive groups depending on postsecondary education status and labor force status in February of 1984. The five categories are (1) out of labor force, (2) unemployed, (3) employed, (4) enrolled in a four-year college, and (5) enrolled in a two-year college. If the respondents stated that they were both a student and employed, they were asked if they were primarily a student or primarily employed during the time period in question. In cases in which the respondents were both enrolled in a postsecondary institution and in the labor force, they were coded as in a college regardless of their reported primary activity. In cases in which the respondents were in the labor force, enrolled part-time in a postsecondary institution, and reported they were primarily employed, the respondents were coded as employed.

## Variable Definitions

*Academic Variables*

Composite mean scores are reported for the base year and first follow-up. Total course credits using HSB subject area codes are used. Carnegie units in English and mathematics are reported. The Carnegie unit has been standardized across all schools.

Grade point averages are provided through HSB's analysis of secondary school transcript data. The grade point average is calculated based on courses defined in the SST taxonomy and those with a range of (0-4).

*Extracurricular Activities*

Frequencies of extracurricular activities represent the percentage of individuals who participated in a given school-sponsored activity, without regard to whether a school did in fact sponsor that particular activity.

In the base year survey (10th grade), students could report participation in up to 12 activities; in the first follow-up survey (12th grade), students could report participation in up to 17 activities. It should be noted that participation in sports is defined differently in 10th and 12th grades. In the base year, all participation in extracurricular sports was captured by a single variable, while in the first follow-up, students were asked about their participation in "varsity" and "other" sports.

*High School Work*

Hours worked in 10th and 12th grade reflect hours worked per week for pay on the respondent's current or most recent job, not counting work around the house. Wages represent the respondent's self-reported hourly wage at the current/most recent job.

**Variables Used in the Wage Model**

Wage regressions include a standard set of control variables: race, base year family income, whether respondent lived in a single parent family in the base year, parents' highest level of education, number of siblings, and region.

An individual's race is coded as either (1) white, (2) African American, (3) Hispanic, or (4) other. The family income variable represents the midpoint value of the income category selected by the respondent in the base year. Single parent families are defined as families in which there is exactly one biological parent or other guardian. The parental education variable reflects the highest level of education reported by either of the respondent's parents. The sibling variable represents the total number of siblings (inclusive of stepsiblings) reported by the respondent; this total does not include the respondent. Region is defined as the Census region in which the respondent's 1980 high school is located (northeast, midwest, south, or west).

The respondent's wage in 1984 (two years after high school graduation) is created from the "annual earnings" and "average hours worked per week" variables in the 1984 data. Annual earnings were divided by 52 to generate weekly earnings. Weekly earnings were then divided by the average hours worked per week to arrive at the hourly earnings or "wage." Values of zero and values greater than $100 per hour were recoded to missing.

## *National Educational Longitudinal Study of 1988 (NELS:88)*

In 1988, approximately 25,000 students in the 8th-grade cohort were sampled from across the nation by NCES. Data were collected from students and their parents, teachers, and high school principals and from high school transcripts. Cognitive tests (math, science, reading, and history) were administered during the base year (1988), first follow-up (1990), and second follow-up (1992). Third follow-up data was collected in 1994, when most sample members had completed high school.

Three samples were created using the NELS:88 third follow-up restricted release data file (approximately 14,000 cases): (1) Education Status in 1992, (2) Ability Quartile, and (3) Education or Labor Market Status in 1994.

## Samples

### *Education Status in 1992*

This sample was categorized into four mutually exclusive sections: (1) high school graduate in 1992, including individuals who received a high school diploma in 1992 and excluding late graduates, early graduates, and anyone born before 1972; (2) dropouts, including individuals without a high school diploma, GED, or certificate by the end of 1992; (3) GED, including individuals that obtained a GED or certificate by the end of 1992; and (4) other category, including individuals born before 1972, early graduates, and missing values.

### *Ability Quartile*

The ability quartile sample categorizes individuals by quartile ability in 1992. Although only mathematics results are presented, reading quartiles were also analyzed. (Variables used F22XMQ [mathematics quartile (1 = low)] and F22XRQ [reading quartile (1 = low)]).

Students completed a series of cognitive tests in reading comprehension, mathematics, science, and history/citizenship/geography. The reading comprehension test consisted of 21 multiple choice questions that measured the students understanding and interpretation of five reading passages. The mathematics test included 40 questions requiring students to make quantitative comparisons and answer work problem, graphic, and geometric figure questions. Students were given 21 minutes to complete the reading subtest and 30 minutes to complete the mathematics subtest.

### *Education or Labor Market Status in 1994*

This sample categorized individuals into five mutually exclusive groups depending on postsecondary education status and labor force status in February of 1994. The five categories are (1) out of labor force, (2) unemployed, (3) employed, (4) enrolled in a four-year college, and (5) enrolled in a two-year college. If the respondents stated that they were both a student and employed, they were asked if they were primarily a student or primarily employed during the time period in question. In cases in which the respondents were both in the labor force and enrolled in a postsecondary institution, they were coded as in a college regardless of their reported primary activity. In cases in which the respondents were in the labor force, enrolled part-time in a postsecondary institution, and reported they were primarily employed, the respondents were coded as employed.

## Variable Definitions

### *Academic Variables*

Mathematics and reading IRT estimated number right mean scores are reported for the base year, first follow-up, and second follow-up. Total course credits using HSB equivalent subject area codes are used. Carnegie units in English and mathematics (HSB) are reported. The Carnegie unit has been standardized across all schools:

(F2RHEN_C F2RHMA_C)

The cumulative grade point average for last year of school attended has not been standardized. Some values exceed 100% because of quality points awarded for advanced courses.

### *Extracurricular Activities*

Frequencies of extracurricular activities represent individuals who participated in a school-sponsored team sport. Furthermore, the sample excludes students that did not participate because their school did not sponsor the extracurricular activity. Additionally, in the second follow-up, individual and team sports were collapsed into two categories; therefore, the frequencies reported for 12th-grade participation in team sports and total number of extracurricular activities may be underestimated. For example, in the first follow-up, if respondents participated in baseball and basketball, then they would report participating in two team sports. If respondents participated in baseball and basketball in the second follow-up, then only one team sport would be counted.

The total number of activities participated in 10th and 12th grades were topcoded at 8 and 7, respectively.

### *High School Work*

Hours worked in the 8th grade do not include chores around the house and reflect hours worked per week for pay on the present or most recent job. In the first follow-up, students were asked how many hours they usually work a week at their current or most recent job which included work in the summer. In the second follow-up, the responses reflect hours usually worked each week at the current or most recent job during this school year. Students were not asked about earnings in the base year. Earnings in the first follow-up reflect earnings per hour at current or most recent job (including summer jobs), and in the second follow-up, earnings per hour are reported for the current or most recent job during the school year.

**Variables Used in the Wage Model**

Wage regressions include a standard set of control variables: race, base year family income, whether respondent lived in a single parent family in the base year (1987), parents' highest level of education, number of siblings, and region.

An individual's race is coded as either (1) white, (2) African American, (3) Hispanic, or (4) other. The family income variable represents the midpoint value of the income category selected by parents in the base year. Single parent families are defined as families in which there is exactly one biological parent or other guardian. The parental education variable characterizes the level of education attained by the parent with the highest reported education level. The sibling variable represents the total number of siblings (inclusive of stepsiblings living at the same residence) reported by the respondent. Region is defined as the Census region in which the respondent's 1992 high school is located (northeast, midwest, south, or west). Missing values of control variables were replaced by a constant value, and an additional dichotomous variable was included to distinguish and hold separate the replacement values.

The respondent's hourly wage in 1994 (two years after high school graduation) is created from the "total monthly earnings" and "average hours worked per week" variables in the 1994 data. Monthly earnings were divided by four to generate weekly earnings. Weekly earnings were then divided by the average hours worked per week to arrive at the hourly earnings or "wage." Values of zero were recoded to missing.