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ABSTRACT

This case study focused on a biotechnology education and training program that includes 2 years of science coursework at the high school level, a year of science coursework at the community college level, paid summer laboratory internships for the high school students, and a year-round co-op job for the college students. The study was conducted in an effort to highlight how diverse environments provide students with access to different types of skill development opportunities and to identify how the knowledge and skills gained in the out-of-school environment take on new value and meaning when connected with the school experiences. Data came from the analysis of the files of 61 focal students and interviews with 22 students, 3 high school teachers, 3 community college instructors, and 4 co-op supervisors. Findings show that the diverse environments give students access to a critical set of skill development opportunities through all three components: work, high school, and college. Students link their experiences across four dimensions of scientific practice: scientific tools, teamwork, organizing data, and time management. The skills they garner become resources, and the resources support their progression on a science educational and career pathway. (SLD)

Scientific Skill Building: Linking High School, College and Work

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Abstract

This paper analyzes the skills students develop in school-based and work-based components of a biotechnology education and training program. Each component (high school, college, internships) provides access to a critical set of skill development opportunities. The high school component provides access to the basic tools, techniques, and concepts of biotechnology; later, this foundation enables students to understand science in a more academic context and to transition successfully into industry laboratory settings. The college component gives students access to a deeper conceptual understanding of these tools and concepts, as well as access to the higher education environment; students who may never have gone to college pursue higher education. The work component offers access to industry experience and the opportunity to apply laboratory skills; this component is the critical entree to the biotechnology industry and motivates students to do well in school. Students link experiences in high school, college, and work across four dimensions of scientific practice (scientific tools, teamwork, organizing data, and time management). Thus, knowledge and experience in one component takes on value and new meaning when connected with activities in other components.

Methodology

This study focused on a biotechnology education and training program coordinated by Berkeley Biotechnology Education, Inc. (BBEI). Two high school career academies (Biotech Academy, Berkeley High School in Berkeley, CA and Health and Bioscience Academy, Fremont High School in Oakland, CA) and one community college (Laney College in Oakland, CA) work in partnership with BBEI to implement the program. The program studied reflects elements of both School-to-Work and Tech Prep program models. Like school-to work, the program links school-based learning and work-based learning through connecting activities. Like Tech Prep, the program links two high schools and one community college.

Students participate in a three year program with a coherent sequence of work-based and school-based learning activities, including science coursework during two years of high school and one year of community college, summer internships as high school students, and year-round co-op jobs as community college students. Over 50 biotechnology and health related laboratories have offered work-based learning experiences to the program participants.

This paper is based on a qualitative study of the BBEI program conducted while working as both a researcher and practitioner in the setting. (My practitioner responsibilities were to find work-based placements for students, monitor students' progress at school and on the job, and assist high school teachers and community college instructors with laboratory and academic curriculum development.) Being a researcher/practitioner allows for long-term participation and understanding of the setting. As Erickson (1986) notes, fieldwork involves long-term participation and that an individual involved in the setting can be an "unusually observant participant who deliberates inside the scene of action."

A case study approach was used to study the details of this particular site, from the perspective of student participants. Qualitative research illuminates the worldviews that students form about their participation in high school, college and work settings. For this study I analyzed 61 focal students' program files and interviewed 32 participants—22 students, 3 high school teachers, 3 community college instructors, and 4 co-op supervisors. Each student's file included: program application, applications for internships and co-op jobs, written learning objectives, co-op and interns supervisor ratings, written co-op papers, college applications and resumes. Each interview was approximately one hour long. Interview guides covered topics related to experiences in co-op jobs and internships, high school and college, relationships between school and work, and structures that helped students complete the program.

Three data analysis phases were used to organize the material presented in this paper. First, data was analyzed and grouped into a broad category called skill building (other broad coding categories included: relationship building, career pathway, and youth participation). Skill building statements were then sorted into sub-categories about technical competence, personal and social competence, and academic achievement; categories suggested by Hamilton and Hamilton's research (1997). However, this grouping scheme did not capture the way students described their experiences. Students did not separate the skills into these categories, but instead described how each site (high school, college, and internships/co-op jobs) gave them access to different opportunities and made critical contributions to their skill development. Thus, students emphasized that different environments provided access to different skill development opportunities.

Statements were reorganized according to the key contribution of each setting. It is important to note that the themes of technical competence, personal and social competence, and academic achievement are consistently noted by students and that these themes gain value and meaning as students move across the three settings. Throughout written documents and interviews, students explained how experiences in one environment added to experiences in another and how, upon reflection, the connections between experiences in a variety of contexts was understood.

The Skills Debate: Skill Gaps versus Access to Skills

Proponents of school-to-career programs highlight that through a combination of school-based and work-based experiences students can gain technical, personal and academic skills. The question of skill development can be framed as either a skill gap (or a list of skills to be mastered by students) or as a problem of providing access to environments that allow for skill development. New vocationalism highlights the importance of engaging students in more than one context (e.g., school and work, high school and college).

There is debate surrounding the position that current high school graduates lack the "new basic skills", academic skills like mathematics, literacy, and problem solving, and soft skills like the ability to work in groups, manage time, and communicate (Murnane and Levy, 1996; Holzer, 1997). Proponents of the new vocationalism highlight the importance of shifting the focus on content from conventional academic programs to programs that combine academic and vocational content, and shifting the focus on pedagogy from skills and drills to meaning-making approaches (Grubb, 1996). Combining academic and vocational content provides opportunities for students to develop technical competence, personal and social competence, and to increase academic achievement (Hamilton and Hamilton, 1997; Stasz and Kaganoff, 1997).

Others suggest that skill development is dependent on having access to environments that provide access to skills. Collins, Brown, and Newman (1989) suggest that cognitive apprenticeships should extend learning to diverse settings so that students learn how to apply their skills in varied contexts. Still other researchers emphasize the importance of the tools, knowledge, environments, and people that students have access to and participate in (Hull, 1997; Moore, 1999).

BBEI's program can be conceptualized as a system that provides students with the opportunity to develop skills in a variety of contexts—high school, college and work. In other words, by participating in a variety of settings, students are given access to a variety of tools, knowledge, environments, and people. By having access to different environments, students develop technical competence, personal and social competence, and experience an increase in academic achievement. Each setting contributes to students' understanding of scientific practice, which has four dimensions—scientific tools, teamwork, organizing data, and time management.

High School Component: Lab Tools, Equipment and Procedures

The high school component of BBEI's program is an environment that provides access to a variety of basic scientific tools and skills that serve as a foundation for the study of biotechnology. These basic tools are particular instruments—pipettes, pH meters, petri plates, as well as lab books and protocols, lab partners, and math skills. In interviews and in written documents, students frequently cite long lists of tools and equipment that were learned in the high school component. This foundation, the familiarity with equipment and basic procedures, enables students to expand understanding of scientific concepts and procedures in a more academic context and to feel comfortable in laboratory work settings.

At the end of their high school junior year, students complete an application for a summer internship. In response to the question, "Describe the lab and math skills you have learned that you feel will help you in an internship position," students typically note a variety of tools and procedures.

> Algebra calculations, spectrophotometer (spec 20), scientific notations, metric system, following protocol, scale (balance), autoclave/sterilizer, pipetting/micropipette, streaking, aseptic techniques, making media, pour plates, DNA extractions, serial dilutions, laboratory notebooks. (Student 49, File, Intern Application)

> I have learned counting bacteria, metric conversion, balances and scales, how to use a microscope and scientific notations. I also learned how to accomplish a project while working with a lab partner. (Student 03, File, Intern Application)

It is interesting to note that in addition to lab and math skills, students often list the use of laboratory notebooks and following a protocol, as well as working with a lab partner, as answers. In this setting, the laboratory notebook and protocols can be thought of as basic tools for organizing a laboratory experiment. The lab partner can be conceptualized as a basic tool for teamwork. These basic tools will later take on additional meaning when students are exposed to the documentation and teamwork required in scientific work settings.

In interviews and reflection papers (written during internship/co-op job experience) students also describe the high school program in relation to the tools used. Familiarity with scientific tools used in biotechnology jobs is one way that students can connect school learning with the work environment. Thus, as Collins et al. (1989) suggest, students extend learning to diverse settings. As students commented in interviews and reflection papers,

> At high school you are working with tools and instruments. How to hold a pipette, the angle. Serilizing, like tilting a flask so that things from the top can't fall in. (Student 40, Interview)

> At Berkeley High it was practical skills rather than all books. In Fermentation it is very hard to connect. In class we ran gels, did DNA extraction, these might apply in other jobs. We grew cells in the petri dish and in overnight cultures, but that is not like fermentation. I do use the microscope, the hemocytometer to do cell counts, viability, and to calculate the number of cultures per milliliter, the pH meter, and pipettes. At Berkeley High you get exposure to the skills. People do different jobs, you can't really prepare for every job. (Student 21, Interview)

> I learned a lot about plates in high school, because we poured a lot of plates in biotech 1 through 4. This helped me understand more at my job now because I knew what the plates were for and what they do. (Student 31, File, Co-op Paper 2)

In each of these responses the focus is on particular tools--pipettes, microscope, hemocytometer, pH meter, petri plates. Students make connections to the high school component by noting the tools they learned to use and how these tools are related to advanced equipment used in biotechnology work settings.

Students recognize and understand the high school program provides access to the basic tools of science, echoing remarks by teachers and program documents. High school teachers, like their students, describe the program in terms of giving students access to scientific tools used in the biotechnology industry.

A Berkeley High school biotechnology teacher suggests that the primary focus of the biotechnology class is to provide students with access to the basic tools, equipment, and concepts of biotechnology.

> Students learn how to use the basic tools and equipment of biotechnology, the microscope, centrifuge, gels. They learn concepts of microbiology, cells, how cells reproduce, how to manipulate cells. (High School Teacher 3, Interview)

A Fremont High School biotechnology teacher highlights that giving students access to the tools of biotechnology provides the starting point to understand the academics behind a particular procedure.

> I give them access to a bunch of tools, which can be an outlet for their energy. It can open the doors to the more academic stuff. I've learned that the content doesn't have to come first. The tools give you a way to back into the content. With PCR we did it, but they didn't know what it was for. If you do the skill first then you have a path to get to the academics. (High School Teacher 4, Interview)

Like the students, teachers focus on tool use as the primary function of the high school component. Interestingly, teachers also note particular content areas (e.g., microbiology) and that the tools can open the discussion for exploration of scientific content. Consistent with Grubb (1996b) who suggests the importance of combining academic and vocational content, teachers and students describe the high school program as combining scientific tools with basic concepts to provide a foundation in biotechnology.

The BBEI certificate, which students receive upon graduation from the high school component, also emphasizes the importance of basic tools and techniques and notes that the skills gained in the classroom setting are expanded upon during the internships in work settings. The excerpt below appears at the top of the certificate students in the program receive upon high school graduation, this description is followed by a list of tools and concepts mastered in the high school program.

> The student named on this certificate graduated from a two year high school biotechnology program. S/he utilized the tools and techniques from the bioscience industry to prep media, grow and maintain cell cultures, and conduct experiments in molecular biology and biochemistry. Academic learning was expanded and reinforced through salaried, hands-on, summer internships in local biotechnology and health care laboratories. (Program Document, High School Certificate)

High school students, teachers and college instructors emphasized that while the tools and techniques provide a basic foundation, the high school component does not systematically provide access to why the tools and techniques are important. In the next section we will see that this dimension of meaning is the critical contribution of the college component. It is important to note that the high school program does not have a specialized textbook. Students are taught the concepts of biotechnology via laboratory activities.

Below, a student highlights that the high school program is fun and provides access to basic skills like pouring plates. She notes that in work settings advanced skills are taught, but that there is a lack of explanation about the background behind procedures. She suggests that a textbook would help students be prepared for the college component when science textbooks are used and disciplines (biology and chemistry) are separated.

> There should be more bookwork in the high school experience, more why we do this, more of an introduction to microbiology. In high school it is fun to pour plates, you don't have a book, not much why, it needs more biology. In college the disciplines are separated, in high school they are combined. High school is fun, you learn what bacteria is, you learn plating, I didn't know why. At the job things are ready made, but you get more background, you get super skills, you learn how to use the instruments, the procedures are set, there is not a lot of explaining. (Student 23, Interview)

High school teachers and college instructors echo the need for more explanation and background about scientific tools and techniques, as well as the need for use of a textbook in the high school program. As high school teachers and college instructors commented in interviews,

> We need more content in the junior and senior year, we need to explain WHY we are doing what we are doing. We need to use a textbook. I think a textbook sends a more serious message. (High School Teacher 3, Interview)

> High school is repetitive daily work, they learn by rote. College is more independent. They get a good introduction in high school, but they would feel more comfortable in college if they knew more. (College Instructor 1, Interview)

Interestingly, students note that the high school program contributes to their academic development beyond familiarizing them with the basic tools and techniques used in science. They cite the utilization of a competency based grading system (where students must repeat assignments until they earn an A or B) as being key to their academic success. In the excerpt from a scholarship essay below, the student suggests that having to maintain an A or B in the biotechnology class motivated her to work harder in other classes as well:

> This program has opened up a lot of doors for me. In the last past year and a half my grade point average has increased a lot. While being in the Berkeley Biotechnology program I had to maintain an A or B in the class. This made me work harder in my other subjects to keep those grades up also. If I were to have fallen behind in my math class than I may have messed up with the math part of my biotech class. This made it easier for me to strive harder, just work at my best to make the best grades possible. (Student 27, File, Scholarship Essay)

While the high school component provides access to the tools of biotechnology, students recognize that there are disciplines beyond science which are necessary for scientific work.

The high school component contributes to student skill development by providing access to the basic tools and concepts of biotechnology in the context of hands-on laboratory classroom activities. The high school component can be thought of as one part of a three part system that meets the goals of new vocationalism. It combines academic and vocational skills and focuses on meaning making—in this case, how the tools are used in another context, work. For students that leave the program after high school, the basic skill foundation is expanded only through internships in industry. Students that continue on to the college component have access to gaining a deeper conceptual understanding about how the tools work; in addition, they gain familiarity with a tool, the textbook, which is essential to success in college.

College Component: Broader Concepts and the College Environment

The Laney College component of BBEI's program is an environment that provides access to a deeper conceptual understanding of biotechnology tools and techniques, as well as access to the higher education environment and community. The increased demands of the college component include a large volume and intensity of academic work plus a concurrent co-op job that requires 20 hours of work per week. Students state that the college component builds upon the high school component by providing detailed background information about how instruments and procedures work. In describing the college component, students focus on the meaning of techniques, or the details behind a procedure rather than on the basic tools. In the statement below, the student highlights the importance of learning the role of each solution used in an isolation protocol, essentially the detail behind a procedure.

> At Berkeley High we isolated the DNA of an onion. We just did it. At Laney we went into deeper depth. We learned about how buffers work with DNA. We went step by step about what each solution does. (Student 03, Interview)

Another student suggests that in college he learned not just how to follow a procedure, but also how difficult it was to design the primers used as a part of the experimental procedure, and the set-up required to begin a procedure.

> At Laney we went into more depth. In high school we would learn a new technique every week. At Laney it was in more detail. In high school it was like basic training. We learned about PCR primers, gels, how the bands break apart. The real training was at college. We learned exactly how the primers worked, how primers are designed, even how hard it is to make a primer. (Student 30, Interview)

Another student highlights the importance of learning "the education part of biology and chemistry," in other words, the background about the stains and organisms she as using in the lab.

> I depend on my teachers to teach us what we need to know for the labs we do. To tell us the education part of chemistry and biology. Things like the stains and the microorganisms, the types of molecules like DNA, and E. coli, the shapes of organisms whether they are gram positive or gram negative. At work you learn lab skills. (Student 46, Interview)

College instructors are aware of the importance of providing students with a foundation for understanding instruments, procedures, and the reasons for using them. The instructors do not have the same caliber of equipment as the industry partners, and they admit that they leave advanced lab skills to be taught by industry. They envision their jobs as important in providing the "why" of biotechnology principles. As seen below, a Laney College instructor suggests her goal is to emphasize the principles behind particular procedures and equipment.

> Students tell me about their jobs. They work with more sophisticated equipment at work. Here they learn the principles that the equipment is designed for and I try to emphasize why we do things like dilutions. Students do dilutions at the job, they make media, they have to keep cultures sterile. Some things I don't have the equipment for like DNA analysis using PCR. These procedures can be done at work. (College Instructor 2, Interview)

Another Laney College instructor suggests that laboratory skills are mastered by repeating a particular procedure and that it is the co-op jobs that provide this repetition. She describes the role of the college classes in providing the foundation for understanding.

> I'm not sure how much we can teach the skills. We can provide experiences, but unless we repeat it again and again they don't master the skill. We only do lab once per week, the job gives the repetition. School and the job serve two different functions. The job is to teach them how to do their job, in school we teach them why they would want to do it. Our job is to give the foundation for understanding. (College Instructor 5, Interview)

Most students note that the tools in the college program are not as well maintained or up-to-date as those available at their high schools. Industry donations of equipment and supplies to the high schools have taken place for a number of years. In addition, the BBEI program purchased up-to-date equipment for the high schools, but not for the college.

> At Laney the equipment was old. I expected Laney to be more qualified. Some of the stuff was broken and not useful. Fremont had much newer equipment. (Student 47, Interview)

The lack of emphasis on technical skills, and a focus on academics, is evident in the certificate that students receive upon graduation from the college component. It is quite different from the high school certificate and emphasizes the courses taken, or disciplines covered, rather than the tools and procedures used. The excerpt below appears at the top of the certificate that students receive upon graduation from the college program, this description is followed by a list of tools and concepts mastered in the college program.

> The student named on this certificate graduated from the Bioscience Career Institute at Laney College which is aligned with a two year, four-semester high school biotechnology program. The college program includes four college level science courses: Introduction to Biology, Microbiology, Inorganic Chemistry, and Organic/Biochemistry. Courses focused on the concepts and skills necessary for entry-level employment in bioscience laboratories, production facilities, and health care setting. (Program Document, College Certificate)

While the college component provides access to conceptual understanding of scientific instruments and techniques, it also provides students with experiences to college level coursework and the college environment. Students, high school teachers, and college instructors note that the volume of work and topics covered in college is greatly expanded from high school. Whereas students use words like "fun," "hands-on," and "basic training" to describe the high school component, this vernacular changes to "study," "textbook," and "more depth" when describing the college component. The difference between high school and college in relationship to the use of textbooks is starkly noted. Below, students highlight that in college expectations are higher and everything counts.

> At Berkeley High there was not much books to read or study from. It was the basics at Berkeley High. Laney is stricter. They expect more. They expect more homework and more reading. (Student 03, Interview)
>
> In college it is very important to get everything. Everything was on the test. Everything counts for a grade. (Student 01, Interview)

As seen below, a Laney College instructor suggests that college level introductory science courses typically cover a broad range of material in a short amount of time (a semester).

> I think it is a challenge for the students to absorb the large amount of data in micro. It is a very broad subject with diseases, the immune system, distinguishing cells from viruses. Micro is a lot to learn in one semester. (College Instructor 2, Interview)

A high school teacher suggests that the lack of a biotechnology textbook in high school leaves students under-prepared for using a college science textbook.

> They don't know how to step up to the higher standards in a different structure. They have a textbook in chemistry, but it isn't used much, we don't use a textbook in biotech. They don't know how to read a science textbook, they have gone through 4 years of high school and never had to use a science textbook. They get to Laney and the language and sheer volume of work is hard for them. (High School Teacher 6, Interview)

In addition to having access to a deeper understanding of biotechnology tools and scientific disciplines, students also have access to the college environment where new behaviors can be observed. BBEI program students notice the mature conduct of the other college students. They are aware that college and industry work settings require maturity and professionalism. Below, a student and college instructor describe the college environment and another student explains what professionalism means in the work and college environments.

> They don't have the mind mentality of the high school. Some of them seem more mature acting, their behavior is a little bit more serious, like it kinda should be. I mean at lunchtime people are just sitting up there talking, you see people over in the corner doing work, their homework, you know you see people studying or whatever. That's the reason why it's different. I mean I think they seem, they act more mature. (Student 05, Interview)

> Beyond the skills and content the behaviors are the most significant. They see other people in a college environment, they have to show up or there are repercussions, they learn how to behave in certain/different settings. They learn to communicate their needs, to express themselves. The co-op jobs send the same message. To be there, to communicate with elder supervisors, to be responsible for their actions. (College Instructor 5, Interview)

> When in a professional environment like your job place it is best to act in a professional manner. Professional behavior shows responsibility, communication skills, and ethics. Using appropriate language is important, no profanity, slang or gender biased language. This shows that you have respect for yourself, and the people around you. Being professional at school is just as important as being professional at work. Being on time, language, and work habits, all of these are important at school because they lead to being a good student. (Student 49, File, Co-op Paper 2)

Other students emphasize the need to manage time to meet multiple commitments. In the college component, students work 20 hours per week in co-op jobs in industry while also taking 12 hours per week of college level courses (not including homework and study time). Thus, students have the opportunity to develop yet another skill, time management. As students commented in their reflection papers,

> To be able to manage time between work and school, and do it successfully, is a skill that is a lot harder than it might seem and I still have not quite perfected the art. The same goes for just managing time in general. This objective is probably the most imperative in terms of completing this program. (Student 35, File, Co-op Paper 2)

> Saturday is now my favorite day of the week since I get to sleep in. When I wake up I'll try to finish my homework around noon. Then I have to decide who to spend my time with, my mom, my girlfriend, my friends, or my books. There is not enough time to spend the day with all of them. Then it is back to studying the next day. It's hard to resist when my friends come over and invite me to go out. Sometimes I'll give in and go. When I don't go I'll be all mad because I had to stay home and do some more hard studying. (Student 30, File, Co-op Paper 1)

Below, instructors and co-op supervisors echo the sense of increased volume and intensity of commitments that students experience.

> They learn how to study, how to organize themselves as people, they learn commitment and maturity, they learn how to juggle time between school and work. They learn how to manage in the world with multiple commitments. (College Instructor 1, Interview)

> I think students were not prepared with how to balance work and study, at the least the majority of students I worked with. I had to do a lot of coaching with them that they can't sacrifice their school studies, that they need to spend time doing that. I would let them spend work hours doing study if I can. I would see if they needed time to review, especially for exams. I'd give them maybe an hour of the work shift to study. (Co-op Supervisor 3, Interview)

The college component contributes to student development by providing access to detailed background information about scientific tools and procedures used in high school. The college component can be thought of as the second part in a three part system that meets the goals of new vocationalism. It combines academic and vocational education and focuses on meaning making—in this case, building on the foundation of scientific tools and techniques learned in high school.

Internships and Co-op Jobs: Experience and Relevance

The work component of BBEI's program is an environment that provides access to a paid industry job, as well as an opportunity to apply the laboratory skills learned in school. Students frequently state that familiarity with the basic tools attained in high school and internships allows them to feel comfortable, and be successful, in laboratory work settings. While working in industry in internships and/or co-op jobs, familiarity with equipment and basic procedures is utilized with the academic foundation to expand students' knowledge of scientific procedures. In addition, at the industry work sites, time management takes on new meaning in relation to productivity in the work environment.

Prior to the internship and/or co-op job, students review a packet of job descriptions and select their top five choices for interviews. Not all students are accepted into laboratory jobs within a biotechnology company. Students work in a wide variety of laboratories, including biotechnology, healthcare, consumer products, and governmental/state. In addition, some secure administrative jobs when they want to develop computer and/or organizational skills. However, students are primarily interested in securing internship and co-op job positions that require and use their laboratory skills. As students progress from the high school internship to the college co-op job, the desire to have an industry position with hands-on laboratory experiences intensifies. As observed in reflection papers and applications below, students often note the importance of opportunities to utilize specific tools and gain expertise with them.

> At the last few weeks of school we were taught how to use the pH meters, well I'm probably the pH expert, because everything that I make has to have a certain pH. I have finally used an autoclave that we talked so much about, and every kind of test tube and flask and beaker that you can imagine. (Student 06, File, Intern Paper 1)

> I applied for these particular positions because they have lab duties. Last year for my internship I had a desk job where I scanned lab notebooks, it was a good position and good experience. Now I would like to use my lab abilities and skills. (Student 49, File, Co-op Application)

> I learned how to use the CASY, this machine is kind of cool. Instead of using a hemocytometer we use this device. I also learned how to use an EDOS. This is like a pipette which can do many things. I learned how to program it and use it for serial dilutions my supervisor also showed me how to graph and do a regression output, the R-square, the R-value and the square root. Also my supervisor helped me understand more about doing dilutions which I didn't understand very well before. (Student 07, File, Intern Paper 1)

Being in environments that involve applied laboratory skills is important to students. It is interesting to note that students in positions that did not allow for laboratory skill building were often able to identify other benefits of their work experiences, such as being provided with access to industry professionals or access to documentation skills. Below, students in non-laboratory internships describe other benefits of their experience.

> My duties and responsibilities are totally different then my job description, on one hand that's kind of disappointing, but on the other my job is kind of fun. I am basically just an office assistant, but that holds a lot of responsibility. The things my supervisor gives me to do are very serious. The skills that I use daily are: perception and paying close attention to detail. If I don't use both of those I could miss the slightest little things and throw everything off. I have acquired the skill to be patient and take my time to proof papers three or four times. (Student 39, File, Intern Paper 2)

> I did gofer work, not much lab work at my co-op job. I handled biowaste, safety checks, paper recycling, shredding, I was in operations, behind the scenes. I also did autoclaving. I really wanted to do lab work. The DOJ did not give me the skills I desired, but I liked the people there. I was in so many different groups. (Student 23, Interview)

High school teachers recognize that students have an easier time making connections between skills learned in school and on the job when they can utilize the tools or procedures that are emphasized in high school at the industry work sites. A Fremont High school biotechnology teacher notes that the internships vary in the skills they provide, and that students begin to envision their career trajectories based upon the site of their industry work experience. He suggests that assignments given during the summer internship help students to identify what they are learning, thus making the experience larger than just a summer job.

> We are always looking for internships. The health ones don't have as many connections with the class. Places like Roche there is a direct link through the lab work. Highland Hospital and Pets Unlimited move students away from Laney. (High School Teacher 4, Interview)

> Students don't see the connections early on in Biotech 1-2. During the internship the connections are retrospective. Students make connections with the content and the skills. The posters are a good tie in. It starts them to make the connections. The major

improvement I've seen is the assignments during the summer. There used to be no big thing at the end it didn't come together. Now the poster requires them to put the big picture together, they learn more and can explain more. In other intern programs it is a job not an internship. Ours is an internship with a product at the end of the summer. (High School Teacher 4, Interview)

Below, a Berkeley High school biotechnology teacher highlights how she learned about the industry requirements by participating in visits to student work sites.

Visiting all the students on the job I was seeing the breadth of the jobs. It helped me to get an idea about what to focus on. I saw the applications of the skills. It was fun to hear supervisors say I was impressed that the student could use a hemocytometer, or I was upset that she didn't know how to use a spectrophotometer. It gave me a focus. I got a lot of comments about sterile technique that students were well versed in that. I heard they wanted them to have more computer skills. And for the lab books they were not as good as they wanted them to be. Most of what I heard was good. (High School Teacher 6, Interview)

Both students and co-op supervisors note that the focus at the work site, as in high school, is primarily on how to do things, rather than on explanations regarding the scientific concepts behind each procedure. The purpose of the work experience is to utilize basic biotechnology tools and to have the opportunity to perform the skills learned in school at a particular industry job. In the interview segment below the student suggest that the purpose of the co-op job is to learn specific skills for a particular job.

The job stuff they don't really teach you in school, how to deal with a fermenter, troubleshooting it. That's what the co-op job is for, to teach you how to do the stuff, the specific skills that you can't train for all jobs. (Student 21, Interview)

As seen below, co-op supervisors' statements are similar to those of the students and college instructors when describing industry work settings as places to develop skills to do a job, but not places where much procedural background is passed on to students.

We focus on the processes, safety, GMP specific to our SOPs. We are not focusing the basic math skills, they come pretty well prepared with that. We are not focusing on the science skills. We focus on the basics of the job requirements. In general we focus on the how to do it. Infrequently we are able to talk about why things happen. The front line supervisors don't have the time to talk about how things are engineered, or explain what happens if there is a pH failure, what's behind it. In an ideal situation we would be able to do that for all our employees, but we don't have the time or resources to do that. (Co-op Supervisor 1, Interview)

While the emphasis at work is on learning the skills to do a job, rather than on the background concepts, students do receive academic support for college level coursework. In addition to access to the application of laboratory skills, both students and co-op supervisors describe how the work site provides academic support. In reflection papers and interviews students suggest that they receive help with vocabulary, math manipulations, and scientific concepts. Below, two students describe academic support they have received at the work site.

> My knowledge of the terms I've learned was tested in many conversations with my supervisor. We talk about what I'm doing in class, what terms I'm studying and what they mean, we also go over my exams and he asks me how I think I can improve on things before the next test. (Student 23, File, Co-op Paper 2)

> My supervisor helped me at the job and at school. She showed me how to do calculations. She helped me in biology, how different creatures adapt to the environment, and especially when we had to learn about plants—how budding happens and the structure of a plant. (Student 03, Interview)

As seen in the interview statement below, a co-op supervisor emphasizes that having students perform a particular procedure at work helped them to grasp a difficult concept that was discussed in the college level microbiology course.

> The students actually said to me it was good to learn microbial testing of water. Now they were learning the different steps at school. In the micro class they were talking about micro ID's. It was difficult for them to grasp. They found the concept hard. I took out an API strip and had them observe how to do it. There may be insufficient training in school and the work environment can provide them that. (Co-op Supervisor 3, Interview)

All of these statements provide evidence that the industry settings, while not explicitly focused on providing background information for each procedure, do indeed give academic support to students.

At the industry work site, the issue of time management takes on new meaning, beyond simply balancing school and work. Time usage is described in relation to productivity in the work environment. In reflection papers students noted the importance of time management.

> While in training she taught me the great importance of time in the world of science and how to make the most of it. For instance, while my samples would be cooking (figuratively speaking) I would be making up the work groups on the computer for my samples that day or I might record the weights of sample dishes that I will be using in the future. (Student 35, File, Co-op Paper 1)

> I feel that my job performance has improved since my last paper because I am more settled in my position. My time management of routine tasks has helped me to create more time for other things and made me more productive in the tasks that I am currently doing. (Student 23, File, Co-op Paper 2)

As seen below, co-op supervisors suggest that short-term experiments done in school do not prepare students for longer experimental procedures with multiple steps.

> I don't think they were prepared for the length of time it takes to accomplish something. They seemed used to small packets of experiments. They were used to doing one digest and running it on a gel. They weren't used to the longer processes that require follow through, and involve multiple steps. They would say things like, 'This will take a week?' (Co-op Supervisor 2, Interview)

Since industry focuses on job productivity, the work experiences give students opportunities to think about time in terms of their own productivity. Whereas balancing school and work commitments requires time management between two worlds, students learn that efficiency and productivity are also important aspects of time management.

Like the college environment, the industry work experience gives students opportunities to observe and participate in different types of social interactions. The work setting opens up doors to a different social and intellectual atmosphere. In the interview statement below, the student emphasizes having opportunities to observe how others behave in the work settings.

> At Bayer during meetings they would present this year's plan, how many samples would be processed in a year, a diagram of how the work will be done. People would talk and discuss and share their opinion. They would have a snack or lunch. We would sit and listen. Sometimes the meetings were boring, but I got to see how people organize, bring notes to talk about their ideas, and see other peoples opinions. (Student 47, Interview)

Below, a co-op supervisor highlights that students learn how to behave and interact in a professional work setting.

> When they come they are young in age and young in experience. They are learning how to behave and interact in an environment where everyone is older. They learn about being able to focus on the work and not get distracted by outside goings on. It takes time. They observe how people around them are acting. In some cases we tell them it would be better if you did this. A lot of it is soaking up the atmosphere and picking up how people interact differently. They see different kinds of conversations that they might not normally talk about, talk about the work, about politics, about things going on in the world. (Co-op Supervisor 2, Interview)

The internships and co-op jobs bring a variety of new experiences. Students note that in addition to new types of social interactions, new forms of documentation beyond a lab book are required. In industry jobs, the lab book is no longer a simple tool, but a critical process essential to scientific documentation. Standard Operating Procedures is an example of FDA required documentation that students encounter in the industry work sites. Below, students papers reveal new experiences with documentation and recording data.

> We spend the day pulling Production Batch Records and S.O.P.'s (standard operations procedure) we'll issue them to other departments, and people who use them S.O.P. are like recipes for people to follow them while their making the drugs made by Xoma. So actually my supervisor's job plays a big part in how Xoma is ran. Everything that goes on in Xoma is documented. That why we have to pay close attention to detail, because

> someone could get an old S.O.P and use it and that wouldn't be good. (Student 39, File, Intern Paper 1)
>
> I've have also learned how to be organized and how to label everything. I didn't realize how important a label could be. The labeling is put on food that we feed to the animals and books are always kept to keep track of who fed which animal and how much water was used by the gallons. We have sign in sheets for every animal and for all of the three types of water that we use (tap water, deionized water, and sea water) this is how everything is kept in order. (Student 27, File, Intern Paper 1)
>
> My second objective is Good Laboratory Practices or (GLP). GLP's is the process of recording data and how to handle a product more precisely. GLP's come into play when we have rack studies. We record how much the product weighs, what product is, the time we started the project and the time we ended. GLP's are good to have on your resume. They show that you are neat and very organized. GLP's are long and boring, but they are essential in making sure the rack studies go smoothly. (Student 44, File, Co-op Paper 1)

Since industry focuses on documentation, the work experiences give students opportunities to think about recording data in a lab book as a critical scientific documentation process.

The work component provides students the opportunity to apply laboratory skills learned in high school and college in a real context. Industry laboratory work experience is the third of a three-part system in which learning activities in different settings are connected and add up to the goals of new vocationalism—in this case, through work experience.

Skill Building: One Student's Experience

One way to understand how providing access to different environments allows for skill development is to follow one student through his three-year participation in the BBEI program. Carlos (Student 36) participated in the two-year high school program at Fremont High School. The summer between his junior and senior year, he had an internship in a governmental laboratory—a county health department. While he attended Laney College he worked in a co-op job at a consumer product laboratory. Upon graduation from the Laney College component, Carlos accepted a full-time position as a laboratory technician in the microbiology department of the consumer product laboratory. He has worked in that position for the past two years.

During high school, Carlos wrote on his internship application, "I know how to use a pipet-aid, a pipette. I know how to operate the environmental shaker and a spectrophotometer" (Student 36, File, Intern Application). Like other students, he emphasized the tools he used in his high school biotechnology class. In his internship at the county health department he monitored water and stool samples for bacterial contamination. Afterwards, on his resume he noted that he "operated laboratory equipment, like water bath, spectrophotometer, pH meter, autoclave, balances, incubator and other interesting machines" (Student 36, File, Intern Resume). At Laney College in a co-op reflection paper written one year after his internship experience, Carlos wrote about his internship, "There I had for the first time the feel of how it was to work in a laboratory. I was proud to be working with so many advanced technical pieces of equipment"(Student 36, File, Co-op Paper 3). Consistent with other descriptions in this chapter, he emphasized how he utilized the tools used in his biotechnology class to perform particular types of tests in his industry internship position, and that he had a successful transition into laboratory work in an industry setting.

On his college co-op job application he wrote, "The skills that I have gained through the years are how to work safe, how to work in groups as well as independent, and also how to use many different kinds of laboratory equipment" (Student 36, File, Co-op Application). Here Carlos expanded his list of skills beyond laboratory skills to include teamwork and safety, skills emphasized in his internship at the health department.

As a co-op student, Carlos worked in the microbiology department of a consumer product laboratory. He monitored food samples and food containers for contamination. In his final college co-op reflection paper he wrote about his co-op job and his access to higher education at Laney College.

> I've had the opportunity to learn many skills as well as laboratory practices and food sampling procedures. I had the experience of working with many different kinds of foods, by following the Standard Operating Procedures (SOP's). The thing I liked most of my job was all the new challenges I went through. Another thing I would like to talk about is my experience at Laney College. With a year of college classes I have had the opportunity to know what college is really like. To me it was a real challenge to try to keep up at school while also working at the same time. It was different from high school because I wasn't working in high school so it was more challenging and I had less time. The most important thing I had to do was to learn real time management. (Student 36, File, Co-op Paper 3)

Carlos, consistent with other students, notes that his co-op job allowed him to apply the microbiology skills he had learned in high school and at his internship to many different types of food products. He also suggests that enrollment at Laney College provided the opportunity to experience college, as well as a learning opportunity in managing time with increased commitments.

Conclusion

This paper highlights how different settings (high school, college, and work) provide access to different skill development opportunities. Each of the three components in BBEI's program provides students access to different skill development opportunities. The high school component contributes to student skill development by providing access to the basic scientific tools and techniques of biotechnology. In college students gain a deeper conceptual understanding of these basic tools and techniques. The biotechnology industry work component provides access to experience and adds relevance to school learning. If examined in isolation, events in one component might appear to fall short of the goals of new vocationalism (combining academic and vocational studies and moving from skills and drills to meaning making approaches). However, by conceptualizing BBEI's program as a system it becomes clear that knowledge and experience in one component takes on value and new meaning when connected with activities in other components.

Students link experiences in high school, college, and work across four dimensions of scientific practice—scientific tools, teamwork, organizing data, and time management. Students learn how to use scientific tools and techniques and make connections to advanced equipment used in biotechnology laboratories. They develop a broad definition of teamwork including lab partners, lab groups and company organizational structures. Students' notions of organizing data are refined over time from simply recording data in a laboratory notebook to attending to multiple experimental variables. Finally, they develop, over time, strategies to face time management challenges by multitasking and focusing on job productivity. The skills garnered become resources, and students draw upon these resources to support their own progression on a science educational and career pathway.

Dimensions of Scientific Practice

	High School Lab Tools, Equipment and Procedures	**Community College** Broader Concepts and the College Environment	**Internships/Co-op Jobs** Experience and Relevance
Scientific Tools	**Tools and Techniques** At high school you are working with tools and instruments. How to hold a pipette, the angle. Serilizing, like tilting a flask so that things from the top can't fall in.	**Conceptual Understanding** We learned exactly how the primers worked, how primers are designed, even how hard it is to make a primer. At Berkeley High we isolated the DNA of an onion. We just did it. At Laney we went into deeper depth. We learned about how buffers work with DNA. We went step by step about what each solution does.	**Making Connections** I learned how to use the CASY. Instead of using a hemocytometer we use this device. I also learned how to use an EDOS. This is like a pipette which can do many things. I learned how to program it and use it for serial dilutions. Also my supervisor helped me understand more about doing dilutions which I didn't understand very well.
Teamwork	**Lab Partner** I also learned how to accomplish a project while working with a lab partner.	**Student Culture** I mean at lunchtime people are just sitting up there talking, you see people over in the corner doing work, their homework, you know you see people studying.	**Organizational Structure** During meetings they would present this year's plan, how many samples would be processed in a year, a diagram of how the work will be done. People would talk and discuss and share their opinion. I got to see how people organize, bring notes to talk about their ideas, and see other peoples opinions
Organizing Data	**Lab Book and Protocols** I've learned how to keep a laboratory notebook and follow protocols.	**Data Overload** At Berkeley High there was not much books to read or study from. It was the basics at Berkeley High. Laney is stricter. They expect more. They expect more homework and more reading.	**Attending to Variables** GLP's is the process of recording data and how to handle a product more precisely. GLP's come into play when we have rack studies. We record how much the product weighs, what product is, the time we started the project and the time we ended. GLP's are essential in making sure the rack studies go smoothly.
Time Management		**Balancing School and Work** To me it was a real challenge to try to keep up at school while also working at the same time. It was different from high school because I wasn't working in high school so it was more challenging and I had less time.	**Productivity on the Job** While in training she taught me the great importance of time in the world of science. For instance, while my samples would be cooking I would be making up the work groups on the computer for my samples that day or I might record the weights of sample dishes that I will be using in the future.

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Scientific Skill Building: Linking High School, College, and Work

AERA Annual Meeting 2003 (April 23, 2003)

Vocational Education SIG Paper Session: Work-Based Education: High School and Beyond

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Objectives

This case study research focused on a biotechnology education and training program that includes two years of science coursework at the high school level, a year of science coursework at the community college level, as well as paid summer laboratory internships for high school students and paid year-round co-op laboratory jobs for college students. This study was conducted in an effort to:

- Highlight how diverse learning environments (e.g., laboratory work settings, high school and college science courses) provide students access to different types of skill development opportunities
- Identify how knowledge and experience gained in an out-of-school learning environment (bioscience industry laboratories) take on value and new meaning when connected with activities in high school and college science courses

Conclusions

Diverse learning environments (high school, college, internships and co-op jobs) provide students access to a critical set of skill development opportunities.

- The work component offers access to industry experience and the opportunity to apply laboratory skills; this component is the critical entrée to the bioscience industry, and it motivates students to do well in school.
- The high school component provides access to a variety of basic scientific tools and skills that serve as a foundation for the study of biotechnology. These basic tools are particular instruments—pipettes, pH meters, petri plates, as well as lab books and protocols, lab partners, and math skills. Later, this foundation enables students to understand science in the more academic context of college and to transition successfully into industry laboratory settings.
- The college component provides access to a deeper conceptual understanding of scientific tools and concepts, as well as access to the higher education environment; students who may never have gone to college pursue higher education. In college, students focus on the meaning of techniques, or the details behind a procedure rather than on the basic tools.

Students link experiences in high school, college, and work across four dimensions of scientific practice—scientific tools, teamwork, organizing data, and time management. Students learn how to use scientific tools and techniques and make connections to advanced equipment used in biotechnology laboratories. They develop a broad definition of teamwork including lab partners, lab groups and company organizational structures. Students' notions of organizing data are refined over time from simply recording data in a laboratory notebook to attending to multiple experimental variables. Finally, they develop, over time, strategies to face time management challenges by multitasking and focusing on job productivity. The skills garnered become resources, and students draw upon these resources to support their own progression on a science educational and career pathway.

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Presenter:

Part-time Work During High School: What Effects Does It Have on Post-School Employment, Access to Vocational Training, and Participation in Higher Education?
---Margaret Vickers University of Western Sydney
---Herbert Marsh University of Western Sydney
---Stephen Lamb University of Melbourne

Early Labor Market and Education Returns to Completing a Combined Academic and Vocational Program
---Mario Delci Consortium on Chicago School Research

Scientific Skill Building: Linking High School, College and Work
---Amy Ryken University of Puget Sound

Vocational and Community Adjustment Patterns of Individuals with Mild Mental Retardation and Learning Disabilities as a Function of Graduation from an Illusionary High School Vocational Education Program
---Dorothy Muthert Miami University
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