Building technical capital in the technology education

Ms. Armineh Noravian, San Francisco State University

Armineh Noravian currently works as an adjunct faculty in engineering at San Francisco State University and as an educational research associate. Noravian holds a MS in engineering and MA in applied anthropology (cultural) from San Jose State University. She is currently completing her Ed.D. at San Francisco State University. Correspondence regarding this article should be addressed to Armineh Noravian at armineh@mail.sfsu.edu.

Dr. Patricia Irvine, San Francisco State University

Dr. Irvine is Associate Dean of the Graduate College of Education. She teaches social science research courses and serves on the Executive Committee for the in the Ed.D. in Educational Leadership Program. She has researched the social functions of vernacular literacies and languages in a variety of multicultural contexts, such as the Eastern Caribbean, Navajo Nation, and the Southwest United States.
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Abstract

In spite of targeted efforts to expand diversity in the engineering workforce, only marginal improvements have been made in diversifying engineering education. Today, the majority of students who enroll and graduate with a bachelor’s degree in engineering are white males. To meet the quantity and quality of engineers the nation needs, educators need to do two things. First, they must “tap all talent”, that is, attract a broad group of individuals who are presently under-represented in engineering. Second, educators must restructure engineering education so that students experience early in their training what engineers do on a daily basis.

Because over forty percent of all four-year engineering graduates began their introductory studies in the community college, pre-baccalaureate preparation has drawn close attention. Women, racial/ethnic minorities, and low income students are well-represented in community colleges, but only a small number of these populations graduate with associate’s degrees in engineering and engineering technologies. Research has shown that an interest in engineering as a career impacts persistence. Yet women and other underrepresented students are less likely than their white male peers to have been socialized to do hands-on activities or encouraged to use toys, tools, or gadgets that might promote their interest in engineering.

First generation and low income community college students are underrepresented in engineering because they face barriers to entering and completing an engineering degree in four-year colleges. Research indicates that the majority of engineering students come from at least a middle-class background. Thus, for first-generation and economically disadvantaged students class is an obstacle because they lack the middle-class cultural capital needed to succeed academically.

The research question for this study is the following: What is the role of problem-oriented pedagogical strategies in developing the professional identity and technical capital among community college students in advanced technological education? In this paper, we argue that lack of cultural capital can be mitigated by helping community college students acquire a professional identity. Furthermore, in addition to cultural capital, we argue that success in technology and engineering education also requires technical capital, which is experience with “tinkering,” manipulating tools, doing hands-on work, and knowing the process of solving problems that require technical solutions. Thus, we argue that to increase diversity in technology and engineering education and careers, programs should help students acquire a professional identity as well as technical capital.
To understand how students might acquire a professional identity as well as technical capital, this study investigated the perspectives of students enrolled in a technician level engineering program that incorporated well-structured and ill-structured problems at a community college. The technology program at North-West Community College (NWCC) is a two-year program. In the first year, students learn fundamentals and basic low-tech skills. The learning takes place in courses that incorporate projects with well-structured problems, often with both a theoretical classroom and a lab component. In the second year, students engage in ill-structured problem solving in their technically sophisticated capstone projects that integrate the principles that students have learned during the first year and continue to learn and practice in the second year.

The findings suggest that scaffolding experiences, that is, moving from very well-structured problems to ill-structured problems, allows students to develop technical capital, to form professional identities, and to succeed in pre-baccalaureate engineering education.
Introduction

In spite of targeted efforts to expand diversity in the engineering workforce, only marginal improvements have been made in diversifying engineering education. Today, the majority of students who enroll and graduate with a bachelor’s degree in engineering are white males. To meet the quantity and quality of engineers the nation needs, educators will need to do two things. First, they must “tap all talent” — attract a broad group of individuals who are presently under-represented in engineering. Second, educators must restructure engineering education so that students experience early in their training what engineers do.

Because over forty percent of all four-year engineering graduates began their introductory studies in the community college, pre-baccalaureate preparation has drawn close attention. Women, racial/ethnic minorities, and low income students are well represented in community colleges, but only a small number of these populations graduate with associate’s degrees in engineering and engineering technologies. Data on two-year institutions indicate that 58% of the students in community colleges are women, 40% are racial/ethnic minorities, nearly 38% are first-generation college students, and 57% are independent students who came from families with a yearly income less than $36,000. However, only 0.1% of women, 0.4% racial/ethnic minorities, and 0.6% white students graduate with an associate’s degree in engineering and engineering technologies.

Women and other underrepresented students are less likely than their white male peers to have been socialized to do hands-on activities or encouraged to use toys, tools, or gadgets that might promote their interest in engineering. Research has shown that an interest in engineering as a career impacts persistence, yet underrepresented students are less likely than white males to have experience in “tinkering” or manipulating tools that might spark such an interest.

First generation and low income community college students are underrepresented in engineering because they face barriers to entering and completing an engineering degree in four-year colleges. Studies indicate that majority of engineering students come from at least a middle-class backgrounds. Foer, Walden, and Trytten’s study of a first-generation, economically disadvantaged female student indicated that social class was an obstacle to her success and feeling of belonging in engineering. Students who come from such backgrounds are an “invisible minority” and lack the middle-class cultural capital needed to succeed. In this paper, we argue that lack of cultural capital can be mitigated by helping community college students acquire a professional identity. Furthermore, in addition to cultural capital, we argue that success in technology and engineering education also requires technical capital, which is experience with “tinkering,” manipulating tools, doing hands-on work, and knowing the process of solving problems that require technical solutions. Thus, we claim that to increase diversity in technology and engineering education and careers, programs should help acquire a professional identity as well as technical capital.

To understand how students might acquire technical capital as well as professional identities, this study investigated the perspectives of students enrolled in technician level engineering programs that incorporated well-structured and ill-structured problems at a community college. The technology program at North-West Community College (NWCC) is a two-year program. In the
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The research question for this study is the following: What is the role of problem-oriented pedagogical strategies in developing the professional identity and technical capital among community college students in advanced technological education?

**Literature Review**

As a foundation for understanding the role of problem-oriented pedagogies for community college students, this section reviews the literature about reasons that students attend community college, studies that differentiate between well-structured and ill-structured problems, and studies that discuss the literature on professional identities and how students form professional identities through completing capstone projects.

**Why Students Attend Community College**

Students attend community colleges for a variety of reasons. The cost of attending a 2-year institution is below that of a 4-year institution and the close proximity to students’ home allows students to live at home while attending college, further reducing the financial burden. Furthermore, students needing to obtain employment quickly to support themselves and/or their families are able to obtain skills in a community college in a short time frame and have access to industry jobs that require more than just a high school diploma. Community college students are also likely to have dependent children or family, and be older than 24, and be balancing work, family, and school, and some may also be academically underprepared. Participants in this study who had families and who wanted to become financially independent were eager to obtain the skills needed to get a job. The program at NWCC was intentionally designed to help them do that.

**Well-structured and Ill-structured Problems**

In this study, we examine whether well- and ill-structured problems affect students’ professional identity or technical capital. Well- and ill-structured problems lie on a continuum. It is the complexity of the problem, the clarity of the goals, the certainty of the criteria required to solve a problem, the prescriptiveness of the skills required, and the number of possible solutions or paths that determine where on the continuum a problem resides. Jonassen defines well-structured problems as educational exercises to which a limited number and variety of rules and principles are applied, within set parameters, with pre-determined right or wrong solutions. Ill-structured problems, according to Jonassen, involve learning activities which might have numerous solutions and pathways to solutions, have few parameters, and contain uncertainty or ambiguity in how they are organized and which solutions might be justified. NWCC designed their engineering technology program to incorporate both ends of the well- to ill-structured continuum.
Building Professional Identities

For students to be well prepared for the workplace, they need to have confidence in their abilities to perform in their fields and believe that they can be successful. Thus, technical disciplines often provide students both technical skills necessary in industry and socialize students into professional identities by allowing them to build upon the knowledge gained from courses throughout the program and to practice the product development process. In other words, students learn not just technical skills, but also practice how to apply their knowledge as they would be required to do as engineers in the workplace. Moreover, people working in fields such as engineering need to not just be content experts, but they also need to be highly skilled problem solvers, team players, and lifelong learners. As such, students need to learn how to integrate various forms of disciplinary knowledge that is important in their understanding of how their field is practiced in a real work environment.

Capstone Projects

One way of developing professional identities in students is through capstone projects, which are generally projects performed by students near the end of their programs to prepare them for work in industry. Although there is much literature on capstone projects in engineering education, few studies focus on students’ professional identity development. Dunlap investigated a 16-week final semester computer science capstone project in a university that used problem-based learning as a pedagogical method. The findings indicated that students not only experienced a positive change in their perceptions of their ability and preparedness for being a software development engineer, but they also experienced a change in their professional identities after completing the project; they described themselves as software engineers, not students. Isomottonen and Karkkainen, who supervised 10 years of capstone projects for software engineering students who had finished most of the major undergraduate courses in a Finnish university, concluded that students felt empowered and motivated, had a high level of commitment to their projects, and experienced a higher level of commitment to their occupational identity.

In contrast to the Dunlap and Isomottonen and Karkkainen studies, Dannel’s study of mechanical engineering students in a large western university involved in a capstone senior project found that although the project was intended to help students construct a professional identity, the students in his study did not demonstrate such an identity development. Students perceived their college setting within which they learned design to be very different from the professional context for which they were being trained. This manifested itself at the end of the project in comments such as "if I were a real engineer" (p.25). In this respect, his study demonstrates the difficulty of building a professional identity in an academic environment.

The current study differs from the above studies in a number of ways. First, students at NWCC are community college students and are being trained to be generalist technicians. They learn computer programming and mechanical, electrical, and pneumatics engineering. In doing so, they necessarily acquire a range of low-tech and high-tech skills. Thus, this is a study of students who have to integrate different disciplines in their capstone projects because they are required to know and to perform a broad range of skills in their future workplace. Second, the participants
in this study come from low socio-economic backgrounds or are first in their family to train for a job that requires a two-year college degree. Investigating whether these community college students acquired professional identities in their capstone projects would mean exploring whether they see themselves as individuals who can competently and with confidence apply their knowledge to solve problems, much like technicians would be expected to do in a job.

Developing a professional identity while still a student would suggest that students develop confidence about their abilities to perform the workplace tasks required of them as professionals. Developing a professional identity in community college for a job that requires an associate’s degree may help students overcome the anxieties associated with being first in their family to seek such jobs. Moreover, knowing that what they do directly prepares them for on-the-job skills could motivate community college students to enter such programs and persevere, particularly if they have to make financial sacrifices to be in such a program. This is important for this population because they may not have the family history, background, and experience they need to succeed in their educational and career goals.

**Methodology**

Two cohorts from North West Community College (NWCC) participated in this study. Cohort 1 included six first-year students who were engaged in projects with well-structured problems while cohort 2 included ten second-year students who were engaged in projects with ill-structured projects. The convenience sample of students who volunteered to participate in this study consisted of those who were present, available, and willing to participate at the time that Noravian was present. To protect confidentiality, the names of the community college and the participants have been changed to pseudonyms.

In this qualitative study students were interviewed face-to-face. The interview protocol included open-ended questions about students’ experiences in various projects. Cohort 1 students were interviewed in pairs because that was the students’ preference and each interview took approximately 45 minutes. Cohort 2 students were interviewed individually and each interview took approximately 30 minutes. All interviews were conducted at NWCC, were recorded, transcribed verbatim, and thematically coded. Themes were then organized and analyzed.

The unit of study is the student experience within a project because projects capture the range of activities that instructors perceive is required to perform tasks and learn the course content. Cohort 1 students were asked to compare their experiences in two projects that were different from one another based on the degree to which their instructor directed their activities. Cohort 2 students were asked to compare their experiences in their second year project and a first year project. This approach allowed the researchers to understand whether, and if so, which aspects of students’ experiences in well- and ill-structured problems affected their professional identities and technical capital.

The demographics of the participants reflected the program’s and the county’s demographics in which NWCC was situated. The students were white and from working class backgrounds. The one participant who was female was the only female in the entire program. Some students had entered the program from high school, while others entered the program after being laid off from work.
To determine the level of structuredness of the problems that participants described, the descriptions were compared to the characteristics of well- and ill-structured problems in the literature, which are listed in Table 1 below.

*Table 1- Characteristics of Well- and Ill-Structured Problems (pp.68-69)*

<table>
<thead>
<tr>
<th>Well-structured problems</th>
<th>Ill-structured problems</th>
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<tbody>
<tr>
<td>Present all elements of the problem</td>
<td>Appear ill-defined because one or more of the problem elements are unknown or not known with any degree of confidence</td>
</tr>
<tr>
<td>Are presented to learners as well-defined problems with a probable solution</td>
<td>Have vaguely defined or unclear goals and unstated constraints</td>
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<tr>
<td>Engage the application of a limited number of rules and principles that are organized in a predictive and prescriptive arrangement with well-defined, constrained parameters</td>
<td>Possess multiple solutions, solution paths, or no solutions at all, that is, no consensual agreement on the appropriate solution</td>
</tr>
<tr>
<td>Involve concepts and rules that appear regular and well-structured in a domain of knowledge that also appears well-structured and predictable</td>
<td>Possess multiple criteria for evaluating solutions</td>
</tr>
<tr>
<td>Possess correct, convergent answers</td>
<td>Possess less manipulable parameters</td>
</tr>
<tr>
<td>Possess knowable, comprehensible solutions where the relationship between decision choices and all problem states is known or probabilistic</td>
<td>Have no prototypic cases because case elements are differentially important in different contexts and because they interact</td>
</tr>
<tr>
<td>Have a preferred, prescribed solution process</td>
<td>Present uncertainty about which concepts, rules, and principles are necessary for the solution or how they are organized</td>
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<tr>
<td></td>
<td>Possess relationships between concepts, rules, and principles that are inconsistent between cases</td>
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<tr>
<td></td>
<td>Offer no general rules or principles for describing or predicting most of the cases</td>
</tr>
<tr>
<td></td>
<td>Have no explicit means for determining appropriate action</td>
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<tr>
<td></td>
<td>Require learners to express personal opinions or beliefs about the problem, and are therefore uniquely human interpersonal activities</td>
</tr>
<tr>
<td></td>
<td>Require learners to make judgments about the problem and defend them.</td>
</tr>
</tbody>
</table>
Findings

The findings focus on six first-year projects and six second-year projects. Table 2 lists all the projects students described.

Table 2 - Projects described by students

<table>
<thead>
<tr>
<th>Project Names</th>
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<tbody>
<tr>
<td><strong>1st year well-structured problems</strong></td>
</tr>
<tr>
<td>• Boiler</td>
</tr>
<tr>
<td>• Programmable Logic Circuit (PLC)</td>
</tr>
<tr>
<td>• Principles of technology</td>
</tr>
<tr>
<td>• Electrical systems</td>
</tr>
<tr>
<td>• Electronics</td>
</tr>
<tr>
<td>• Pneumatics</td>
</tr>
<tr>
<td><strong>2nd year ill-structured problems</strong></td>
</tr>
<tr>
<td>• Robot Arm</td>
</tr>
<tr>
<td>• Siemens Programmable Logic Circuit(SPLC)</td>
</tr>
<tr>
<td>• Heating, Ventilation, and Air Conditioning (HVAC)</td>
</tr>
<tr>
<td>• Automated Production Line (APL)</td>
</tr>
<tr>
<td>• Automated Guided Vehicle (AGV)</td>
</tr>
<tr>
<td>• Solar panel</td>
</tr>
</tbody>
</table>

Themes

Three themes emerged: (1) structuredness defined along a continuum, (2) developing technical capital, and (3) developing a professional identity. Each of these themes is discussed below.

Structuredness Defined Along Continuum

The findings here indicate that well- and ill-structured problems in the first and second year projects lie on a continuum. This finding is in agreement with Jonassen. A close examination of students’ experiences in projects with well-structured problems indicates that such projects can have problems that can be well-structured, but they contain components that are not so well-structured.

On the well-structured end of the spectrum was the Boiler project. Students learned about boilers from their instructor and in the lab, they looked at various physical parts of a boiler that they had learned about in their textbooks. Thus, the lab portion provided the students the opportunity to see the principles that they had learned from their instructor and allowed them to do a limited set of tasks which they would be expected to do on the job with boilers.

The Principles of Technology projects were on the well-structured end of the continuum as well. It was described as equivalent to a physics class. Similar to other first year classes, a classroom component and a lab component was included. In the classroom, the students learned concepts of physics and in the lab they worked on problems such as measuring forces, angles, and momentum which would demonstrate the concepts learned in the classroom. All students agreed that in the lab they followed explicit steps to reach a specific objective. They did calculations to get the results that they were expected to get. The instructor signed off on when students had completed each lab session. The students received assignments, quizzes, and weekly homework.
In contrast to Principles of Technology, the Electrical Systems and the PLC projects included components that were less well-structured. In these projects the students learned theoretical concepts in the classroom and applied them in the lab to augment their learning from the classroom. The lab component included wiring up a circuit to perform a specific task explicitly defined by their instructor. If the circuits did not perform as required, students had to learn where they had made a mistake and go through the process of debugging to find and fix the problem. This debugging process was what students found challenging and rewarding. In other words, the mistakes became the problems that they ultimately solved. The mistakes made were not predictable, and finding and fixing the mistakes added a less well-structured component to the well-structured problem that was initially their task in the lab.

In the Electronics project, students learned in the classroom about the basic principles associated with electronics parts, but in the lab they had to figure things out on their own. For instance, students described an instance where they had to test transistors to see if they were functional or damaged. This meant that they had to learn about tools such as multi-meters, do research to collect data on transistors, and test them with the multi-meters. This process required that students knew how to use the multi-meter for this specific application, know what kind of data they needed to collect to test the transistor and what readings indicated that the transistors were functional or damaged. There were no explicit directions from the instructor on how these tasks needed to be performed, which made each step in the process somewhat ambiguous. Checking to see if transistors worked would generally have required following certain sets of steps. However, lack of explicit directions on how to perform this problem and lack of comfort with using the multi-meter made this process ambiguous. Thus, this project was less well-structured because of lack of explicit directions for students.

Lastly, among the well-structured projects, the Pneumatics project started as well-structured problems during the beginning of the term but became increasingly less well structured as the term progressed. At the beginning of the term, students were given a circuit to build in the lab to perform a specific function. The steps for building a given circuit, testing it, and making sure that it functioned as specified were explicitly given to students by the instructor. However, the students were required to figure out the debugging of the circuit by themselves, which helped them develop debugging skills. Thus, much like the Electrical Systems and PLC projects, Pneumatics projects had well-structured problems with a component that was less well-structured at the beginning of the term. However, the problems given to students evolved into a less well-structured as the term progressed. At the end of the term, the final goal for the project was determined by the instructor, but the solution was determined by the students. The solution involved using concepts, rules and materials that students were learning in the classroom and was bound by the parts that were available to them on the pneumatics trainer. Thus, the solution path had become “vague” and increasingly ill-structured as students learned more content and became more familiar with the processes required to solve pneumatics problems.

Students’ experiences showed similar variations as they moved into the second-year where they worked on ill-structured problems in their capstone projects. The capstone projects were technically sophisticated and required content knowledge which the students had acquired in their first year of the program and continued to acquire as they worked on their capstone projects in their second year.
The Robot Arm was the first capstone project for the second year cohort. Although the project involved some coursework, the coursework was mainly to support the lab sessions. In the lab, students programmed a robotic arm to do a variety of tasks such as moving pucks, judging the color of pucks, and sorting and stacking pucks based on their colors. Students used the manual for the robot arm to learn how to program the robot and control the robot’s sensors. Although the students had learned programming, the language required to program this robot was new. A programming language provides the user specific instructions that command the robot arm to perform specific tasks. Each instruction has a known outcome. As such, it is explicit and unambiguous. To learn this language, the students were required to learn the specific programming language used by the robot from the manual on their own. Even though this was a different way of learning, the learning of the programming language was an explicit task. That is, specific instructions had specific outcomes. As such, this part of the problem was well-structured.

At this stage in the program, the students were generally familiar with sensors, but they needed to look on the internet to learn how the sensors on the robot arm functioned. Based on the information they found about each sensor, the students would write the program so that the robot arm would do specific tasks before and after the puck hit the sensor. The information that the students found on the internet provided different options on how the sensors could be used, providing ambiguity to students’ task. Thus, different groups of students who were working on this project used their sensors in slightly different ways to perform the same task. The outcome was that they realized the sensors could be applied differently, i.e. different solutions existed for the same problem even when using the same component. Thus, in this project the process of using sensors, something that they had done in the past in well-structured projects, became a more ambiguous task. Therefore, this part of the problem was not well-structured. Programming the robot required the application of these instructions in a manner that the student believed would accomplish their goal. This process required that the students assembled a sequence of instructions that they thought would control the robot arm's movements in specific ways. This part of the problem was not described in the manual and could be done in many different ways. This exercise allowed multiple approaches and provided space for creativity. It also influenced students’ interactions as they figured out what they had to do, the best approach, or discussed the reasons behind approaches taken. After writing a program for the robot, the students then had to debug their program, which meant trying to figure out why things didn't work as they expected. This part of the problem was ill-structured and increased the challenge level for the students.

In summary, the robot arm was an example of a hybrid project. The project was well-structured in that the end goal was explicitly stated by the instructor. Learning the programming language was also well-structured because the programming language was explicitly defined in the manual. However, using the various sensors was less well-structured (or more ill-structured) because the sensors had characteristics that allowed them to be used in different ways. Lastly, programming the robot arm, i.e. writing a sequence of instructions to accomplish a specific goal, could be done in different ways, which made it the more ill-structured portion of the problem. Thus, the first capstone project that students did at the beginning of their second year was a hybrid project and contained elements that were well-, less well-, and ill-structured.
The APL, AGV, the Solar Panel, and the SPLC projects all had the characteristics of ill-structured projects. In the APL, students worked on a scaled model of a bottling production line. Bottles travelled on a conveyor, were labeled, capped and packaged. Students identified a problem with a part of the production line, which became their project. In the AGV, students worked on the hardware and software of a robot that simulated the automated robots used to move goods and materials in factories. The goal was to have the robot follow a guideline placed on the floor by the students. In the Solar Panel project, students designed a solar panel that tracked the movement of the sun across the sky throughout the year. Lastly, the SPLC allowed students to select any particular aspect of working with an SPLC and produce mechanical, electronics, or software for an SPLC trainer to be used to train students. What these projects had in common was that students selected what particular aspect of the problem they wished to address, decided how to address it, and produced a solution, with the instructor acting only as a guide. In all these projects, the process that students described reflected the characteristics of ill-structured problems, that is, the problem was not well understood initially, there were many ways of solving the problem, the solution was not certain, and there were different ways of evaluating the solution.

Lastly, the HVAC project was a project where students learned, but not through solving a problem. Students worked in teams to learn about the entire HVAC system on their own from the manual. The instructor functioned as a resource for the students and answered questions if asked. The students were given a set of seven or eight questions that tested their knowledge of HVACs. They had to be able to answer questions that related to installation, maintenance, servicing, and troubleshooting verbally at the end of the term. In this project, the end goal was for the students to learn about the HVAC and communicate like an HVAC technician. The manner in which students accomplished this end goal was entirely up to them. Thus, the team members navigated their way, not through directed activities, but through vaguely defined goals. There was no explicit understanding of how the end goal could be accomplished, except that they could accomplish it by working together. Thus, even though there was no problem to be solved, this project had the characteristics of an ill-structured problem oriented learning approach with the problem being that they needed to become knowledgeable about the entire HVAC system so that they could answer the end of term questions, much like they would if they were speaking to a customer in the field.

In summary, what this theme indicates is that this community college technician program begins their first year students with problems that are on the well-structured end of the well- and ill-structured continuum \(^{15}\). Students are then exposed to a hybrid project at the beginning of their second year, and delve into ill-structured problems solving during the remaining part of their second year.

*Developing Technical Capital*

We define technical capital as the cultural competence acquired from tinkering experience (“practical familiarity with mechanical and electronic devices and appliances” (p.61) \(^{29}\), manipulating tools, doing hands-on work, and knowing the process of solving problems that require technical solutions. The students at NWCC developed technical capital progressively as they moved from well-, to not-so-well, to ill-structured projects. First year students were
comfortable with working on well-structured problems, and they reported a sense of accomplishment if their well-structured problem had a component that was not so well-structured. This was the case in the Electrical Systems and the PLC projects where students learned aspects of trouble shooting and became more confident in their ability to find problems and solve them. Another example was the Pneumatics projects, where students began with well-structured problems in the beginning of the term and progressively solved more ill-structured problems as they acquired content knowledge, experience with solving problems, working with their hands, learning about tools and approaches to solving problems.

In contrast, in the Electronics projects where students were given a less well-structured problem, those who did not have the technical background or experience for solving such a problem became lost and confused, while those who had the technical background or experience to deal with a less well-structured problem were able to do so with more ease.

Second year students stated that they enjoyed and made sense of their ill-structured problems in ways that had an impact on their professional identities. Their first capstone project was a hybrid problem which had components that ranged from well- to ill-structured. However, all their other capstone projects exclusively involved ill-structured problems. Students’ experiences with their first year projects and perhaps their first capstone project had developed their technical capital to the degree that they were confident that they could take on and succeed in solving a sophisticated and ill-structured problem.

Learning trouble shooting, becoming more knowledgeable about content and applying that knowledge to solve less well-structured problems, becoming comfortable with approaches to solving progressively less well-structured problems, and gaining experience in solving problems that are somewhat ill-structured are all part of building technical capital. These skills are needed for students to solve the kinds of technically sophisticated ill-structured problems required in further engineering education and careers. These examples demonstrate that well-structured problems are useful as scaffolding to develop technical capital, without which students are not likely to make sense of what they do when presented with ill-structured problems.

Developing a Professional Identity

Both first and second year students perceived that they were learning skills which were necessary for being able to competently perform on the job as technicians, in both well- and ill-structured projects and even in projects where they did not have to solve a problem, for instance the Boiler and the HVAC projects. It is the perception that what they learned would lead to acquiring skills needed for a job that makes them connect their learning directly to becoming a maintenance technician. Students described what they did in these projects as if they were practicing doing what they would be doing in their jobs as technicians. This process is what we refer to as the acquisition of a professional identity 30.

Developing a professional identity in community college students for jobs that require an associate’s degree not only makes learning meaningful for them, it also helps them overcome the anxieties and uncertainties associated with being first in their family to seek such jobs. Developing a professional identity allows students to gain familiarity with what is expected of
them to succeed in their technical education and to become prepared for what would be expected of them in future employment. Thus, acquiring a professional identity in community college will provide underrepresented students with knowledge that they are missing due to lack of middle-class cultural capital\textsuperscript{14}. This is likely to lower the socioeconomic obstacle to success in technical education.

\textbf{Conclusion}

The findings indicate that to increase diversity in technology and engineering education, programs should be designed to (1) build community college students’ technical capital and (2) help them develop professional identities.

Moving students from very well-structured problems to ill-structured problems allows students to gradually build the knowledge and skills that they need to deal with problems that are technically more sophisticated and ill-structured. Such a gradual approach provides students who do not have technical capital, or a background with doing hands-on activities or tinkering, an opportunity to acquire it upon joining technical or engineering programs.

Students develop professional identities for jobs that require an associate’s degree when working on both well- and ill-structured problems that they perceive as necessary for being able to perform competently as technicians. This development helps them overcome the anxieties and uncertainties associated with being first in their family to seek such jobs. It also allows these students to gain familiarity with what is expected of them to succeed in their technical education and to become prepared for what would be expected of them in future employment as technicians. Thus, the acquisition of a professional identity provides them the knowledge that they need to succeed. This kind of knowledge lowers the obstacles presented by their socioeconomic status and lack of cultural capital\textsuperscript{14}.

Finally, a key factor that allows students to connect their experiences with the concepts they learn and their future practices is learning through performing projects. Students in this study reported that technical content combined with the process of learning and applying knowledge to solve a problem was important. In fact, students saw processes such as planning, thinking in certain ways, learning how to learn on their own, and doing research as important as acquiring technical knowledge. These kinds of knowledge can best be acquired through working on both well- and ill-structured problems.

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References


5. Engineering and Social Justice: In the University and Beyond. (Purdue University Press, 2011).


