Introduction

> A true and complex understanding of another's thought becomes possible only when we discover its real, affective-volitional basis.
>
> (Vygotsky, 1987/1934, p. 282)

> . . . with respect to the aims of education, no separation can be made between impersonal, abstract principles of logic and the moral qualities of character. What is needed is to weave them into unity.
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> (Dewey, 1933, p. 34)

To say that the past 50 years has brought rapid advances in science, engineering, and technology is an understatement. Life expectancies have increased from 68 years in 1950 to 78 years in 2004. Engineering takes place on a miniscule scale, 1/100,000th the diameter of a human hair. Regular communication for business and pleasure, once the purview of the telephone and U.S. mail system, now takes place through e-mail and online video conferencing. However, in the midst of unstoppable progress in science and technology, one thing has remained the same.[1] European-American women and people of color continue to choose physical science, engineering, and technology careers at much lower rates than European-American men. The question is why?

Lack of access to knowledge and skills is the most common explanation for why European-American women and people of color do not choose physical science, engineering, and technology-related careers. Some believe that increasing access to key coursework and knowledge will shift career choices among underrepresented groups. However, over the past 25 years, attempts to increase access to

[1] See Stine, D.D. & Matthews, C.M. (2009). The US Science and Technology Workforce. Congressional Research Service Report for Congress.

knowledge has not led to appreciable change in the population of people choosing career paths in science, engineering, and technology. One might argue that changes in access take time, and that we must continue to increase opportunities for underrepresented groups to gain knowledge and skills and wait for the impact on career choices. But, access to knowledge and skill is only part of the explanation.

Choosing a career engages personal inclinations and ambitions and reflects cultural and social expectations about the kinds of people who assume particular positions within American society. In light of these factors, the access to knowledge explanation is too narrow and explains too little. A new explanation is needed that is more holistic and reflective of the social, cultural, and personal nature of pursuing a career or enrolling in a course of study. In this explanation, the central focus shifts from knowledge to people in contexts over much longer periods of time, where knowledge is one part of a much larger picture. Intervening to support students of all ages to study physical science, engineering, and technology becomes a matter of introducing them to an initially unfamiliar world, providing opportunities to see how this new world connects to the personal worlds they already know, and encouraging them to become engaged participants who in turn change the intellectual, social, and cultural landscape as a result of their work.

We take the approach that engaging students of science, engineering, and technology is a matter of developing people while expanding their knowledge and skills. Our central argument is that to fully understand human learning both in and out of school, we must go beyond ways of knowing and doing to identify the ways of being a person in the world that emerge and guide human activity. Learning from this broad view is as much about the complex interaction of personal and collective interests, intentions, emotional commitments, and beliefs about how to be a person in science as it is about personal and collective ways of knowing and doing science. Our approach embraces learning as a human science.

Our book focuses on one classroom of racially, ethnically, linguistically, and socioeconomically diverse fourth graders and their science teacher to make the case for learning as a process of being, knowing, and doing. The book begins with a theoretical account

of learning from this broad view. In subsequent chapters, we analyze how the classroom developed into a socially and emotionally supportive and intellectually rigorous place to learn science. We also provide case studies of four students to follow their trajectories through the classroom lessons and begin to understand how they came to see science as a part of themselves. Our intention is to build a robust, holistic model of learning that honors the complexity of being a scientific thinker and respects long-held insights from Vygotsky and Dewey that thinking is more than a cognitive act.

To Be, To Know, and To Do: An Example

To better understand what we mean by developing people as well as knowledge and skills, we provide a short example from a science unit on balance and building. Through participation in a study to test strategies to increase students' engagement in science, these diverse fourth graders and their teacher discussed complex science concepts and used experimental science and engineering approaches to investigate problems. The excerpt below took place on the eleventh day of a 12-day instructional unit on balance and building. The investigation involved building a tipi using the concepts of tension and compression to guide the design. Just before the excerpt below began, Rosie and Rich had completed a common classroom routine, reporting about their predictions and theories, their results, and the relationship between their predictions, theories, and results to the rest of class. During the report, Rich vocally shared his theory but Rosie did not fully articulate hers. As reporters, Rich and Rosie answered questions from the audience once they finished their report. Emma and Denise were members of the audience assigned to pay close attention to the predictions and theories offered by this group. Their role as audience members was to ask the reporters questions to make sure they heard and understood *all* of the group's predictions and theories. Emma and Denise wanted to hear more about Rosie's theory.

Emma: Did anyone else in the group have a theory?

Denise: Rosie was gonna say one and then Rich was gonna say one. Rosie, what is your theory?

Rich: ***We already said it, I said it.***

Denise:	They were both gonna say a theory.
Teacher:	Do you think they had the same theory or different theories?
Denise:	Different.
Teacher:	Excuse me, time out there's an excellent point being made here, Denise thinks that there's two theories over here . . .[2]
Rich:	***I already said it.***
Denise:	What were you gonna say Rosie? What were you gonna say?
Rich:	***Everybody knows what I said, right?***
Student[3]*:*	No.
Student:	Shhh.
Student:	Not me, not me.
Rosie:	Well, I don't know which one [previously discussed theories] because [pause] . . .
Denise:	Why did you think that was gonna happen?
Rich:	***Because we didn't even start yet when we predicted.***
Denise:	**You made your theory, I want to hear Rosie's.**
Rosie:	Ok, it's just that if Rich didn't cut this (the straw in the middle of the tipi), it wouldn't came out like this.

Sophisticated reasoning is evident on many levels in this short interaction. First, Emma and Denise as students were asking reporters about their ideas – something that is quite atypical in most elementary classroom contexts. This is often viewed as the teacher's role. Emma and Denise also approached their questioning in a way that revealed a deep understanding of theories and theory building. Both students probed the group for what they perceived to be different theories offered by Rich and Rosie. Emma and Denise recognized that they did not understand the alternative theories offered by this group. The teacher marked this important point and drew

[2] A few turns related to a mispronounced name have been deleted here.
[3] In cases where a student's voice could not be identified with certainty, "Student" will be used.

other students' attention to it. As Rosie struggled to articulate her theory, Denise again demonstrated a sophisticated understanding of theory by prompting Rosie with a question. She asked, "why did you think that was gonna happen?" This guidance helped Rosie formulate a response that would count as a theory (i.e., something that explains why or how) in their classroom context.

One could argue that this discussion of how students negotiated knowledge would be a fine place to begin and end an analysis. Embedding this excerpt within a larger analysis of how students' notions of theory building and evaluation developed across all days of instruction would provide a richer picture of students' struggle to understand and negotiate theory building as a key scientific practice. This is the approach we have taken in the past (see Herrenkohl & Guerra, 1998; Herrenkohl, Palinscar, DeWater, & Kawasaki, 1999; Kawasaki, Herrenkohl, & Yeary, 2004). However, the analysis above seems meager given the richness of the interaction. What else is going on in this excerpt?

Take the interaction between Rich and Denise, for example. Denise is an African American girl who was not afraid to take risks and make mistakes. Rich is a European American boy who often challenged other students' ideas.[4] As Denise asked Rosie to articulate her theory, Rich tried to stop her effort by asserting that he had spoken for his group. Denise was not to be deterred. She persisted in asking Rosie for her theory with Rich saying "I already said it" *four times*. As Rich continued to assert himself, so did Denise. She eventually addressed his bid to speak for his entire group by saying "you made your theory, I want to hear Rosie's." In making this statement, Denise persevered and explicitly and skillfully dealt with a sticky social situation in pursuit of a central way of knowing science – generating and understanding alternative or competing theories.

Take Rosie's perspective too. What must it have been like to be in her shoes? She is a talkative and engaged Latina who asked others many questions. Other students, however, did not always respond to her ideas in the same manner. In this case, Denise made an enormous

[4] Profiles of these students are presented in detail later in chapter 4. The descriptions provided here are based on these analyses.

effort to give Rosie the floor to explain her thinking. Rosie benefited from Denise's firm and direct approach with Rich, ultimately gaining an opportunity to express her ideas. All the other students witnessed this interaction and watched Denise publicly validate the need to hear Rosie's alternative theory.

What about Rich? His ongoing attempts to speak for others were tempered by Denise's skillful comment, which recognized his perspective ("you made your theory") while also insisting that he join the group in giving Rosie the floor ("now I want to hear Rosie's"). He accepted Denise's recommendation and yielded the floor to Rosie allowing her to share her theory.

And finally, let's discuss Emma. Emma is a quiet and shy European American student during whole-class time and has more absences than most students due to a medical condition. It was Day 11 of instruction and this was the first question she asked in the whole-class context. She voluntarily decided to join the larger whole-class conversation by initiating an important line of questioning in science.

It is clear even in this short example that to talk about the students' learning in terms of knowledge and skills alone diminishes and dismisses some truly profound and complex human learning experiences. Denise's persisting to understand the group's perspectives, Rich's yielding the floor, Rosie's articulating an alternative theory, and Emma's asking her first question are all crucial dimensions of these students' learning experiences in school science. Their development as people who practice school science was happening alongside and in conjunction with their new ways of knowing and doing science. Yet, our own work and the field in general provides inadequate understanding of how students emerge as participants who use their knowledge and skills in powerful ways. Our accounts of learning lack explanatory power when we focus only on knowledge and skills and neglect aspects of students' development as participants who actively negotiate the scientific process.

These omissions are the impetus for this book. Our contention is that as students become knowledgeable in new areas of study, they are also becoming certain kinds of people in relation to that subject matter, one another, teachers, parents, the larger community,

and their future selves. These ways of being are often left out of our accounts of students' learning in school. Students develop and refine ways of being including interests, motivations, affective orientations toward learning, and personal and social values about what is worth learning and if, how, and why one ought to put certain knowledge and skills into practice. If we are to fully and completely understand human thought and learning, we must engage these processes of being alongside and in conjunction with knowing and doing.

Why Ways of Knowing, Doing, and Being?

We use the terms ways of knowing, doing and being to highlight the active and dynamic nature of learning. Our perspective is that knowing is an activity, a process that resides in practices that are shared by people and accomplished by using tools inherited from our cultural legacies. Ways of knowing and doing is a simple and clear way to express this general idea. Literatures related to school-based learning including subject specific learning (Rutherford & Ahlgren, 1990; Shulman & Quinlan, 1996), learning sciences and cognitive approaches to education (Bruer, 1993; Sawyer, 2006), and sociocultural approaches to learning and development both within and outside of school (Lave, 1988; Moll & Greenberg, 1990) use terms like ways of knowing, habits of mind, and funds of knowledge to connect individual knowing processes to valued cultural and social activities. We will use the terms ways of knowing and doing to capture this kind of valued social and cultural activity. In our case it will include conceptual and epistemological practices that characterize reasoning in school science. These practices are distributed across people and features of the school setting such as values, tools, and common classroom routines and practices.

Ways of being include interests, motivations, emotional commitments, and personal and social values about what is worth learning and how or why one ought to put certain knowledge and skills into practice. At the most coarse grain size, ways of being are patterns of acting and speaking that identify who a person is and what she values in a specific context at a particular point in time. Borrowing

from Hicks (1996), we define ways of being as the expression of "a person in relationship within the everyday world of historical contingencies and emotional and moral commitments." (p. 108) Ways of being do not reside in individual heads and hearts. Rather, they emerge from and are negotiated in social interaction using culturally available tools, including ways of knowing and doing. Studying learning becomes a process of understanding the dynamic relationship between interests, motivations, emotional commitments, values, and ways of knowing and doing to more fully explain students' actions in world.

We have elected not to use the terms identity or identities, although some authors we will draw upon to discuss our work use these terms. There are several reasons we made this choice. First, identity has become a widely used term with multiple meanings depending on author and audience (see Hicks, 1996). Second, theoretical schools that have used "identity" often give priority to either the individual or the social world but not often to the dynamic interaction that exists between them. This is not true of the work on identity that most influences our own (see Greeno, 2002; Holland et al., 1998; Holland & Lachicotte, 2007; Lave & Wenger, 1991). However, in the literature there is a tendency to treat identities as fundamentally properties of individuals (Erikson, 1950, 1968; Harter, 1999; Marcia, 1980) or social worlds (Gergen, 1991; Goffman, 1959) rather than an interaction between individual and social world. Third, and most importantly for us, identity is a noun and therefore gives the impression that it is a product or thing and not a process. Our choice of "being" allows us to emphasize a dynamic process instead of what might be misconstrued as a static product (identity or identities).

Situating Our Perspective in Broader Discussions of the Purpose of Education

We began the book with a discussion of how current approaches to workforce development in physical science, engineering, and technology continue to focus on knowledge and skills as leverage points for changing the demographics of people choosing these careers. We

argued that the access to knowledge approach is inadequate even when workforce development is considered the goal of education. When the purpose of education is defined as creating an educated citizenry prepared to participate in a democracy, a purpose that Dewey and many contemporary philosophers espouse, our broad view of developing people who put knowledge and skills to use is paramount. We see our perspective as situated within these larger movements in the social sciences and humanities to create education for democracy that reflects Aristotelian notions of human flourishing.

Several perspectives in this movement have been important to the conceptualization of our broad view of learning. Toulmin (1992), drawing from Aristotle, argues that today's philosophers and scientists need "intellectual grasp of a theory (episteme), mastery of arts and techniques (techne), and the wisdom needed to put techniques to work in concrete cases dealing with actual problems (phronesis)" (p. 190). The first two dimensions, knowledge and skills, are familiar to those who study learning from social science points of view. What might be less familiar is an emphasis on phronesis, or the idea that practical wisdom guides the use of knowledge and skills as they are applied to actual problems. Phronesis transforms knowledge and skills from decontextualized tools to concrete opportunities for action. People use tools to accomplish personal, social, and cultural goals that are embedded within webs of values and beliefs. Actors are located in particular social and cultural contexts, bring personal motives, feelings, beliefs, and agendas, and use specialized ways of knowing and doing to accomplish their tasks (Burke, 1945).

In applying this approach to education, Nussbaum's (1997) perspective is similar to Toulmin's. She suggests higher education must "cultivate humanity" by supporting students to develop knowledge and skills together with practical wisdom to put knowledge and skills to good use. She argues, "becoming an educated citizen means learning a lot of facts and mastering techniques of reasoning. But it means something more. It means learning how to be a human being capable of love and imagination" (p. 14). Her concern is that knowledge and skills are becoming increasingly separated from contexts of application and action within curricula in higher education. Creating people and communities that can "genuinely reason together

about a problem, not simply trade claims and counterclaims" should be a central goal of higher education (p. 19). She concludes her book by saying, "It would be catastrophic to become a nation of technically competent people who have lost the ability to think critically, examine themselves, and to respect the humanity and diversity of others" (p. 300). She argues that higher education must address this issue of practical wisdom as well as knowledge and skills to meet the needs of twenty-first-century college students. While looking forward, Nussbaum is also pointing back to Dewey's vision of weaving abstract principles of logic together with moral qualities of character.

Flyvbjerg (2001) builds on the philosophical turn to phronesis through his attention to power as it affects putting ways of knowing and doing into action within the social sciences. Flyvbjerg argues that we must consider how power is omnipresent and negotiated, a perspective inspired by Foucault and his question, "how is power exercised?" (Flyvbjerg, 2001, p. 118). This work is important because conflict and resistance and other affective elements that often remain hidden can become more easily revealed when power is examined (John-Steiner, 2000; Herrenkohl & Wertsch, 1999). Some work has taken up this stance within classrooms, examining how power is negotiated among students, teacher, and content during classroom lessons (Barron, 2003; Cornelius & Herrenkohl, 2004; Engle, de Royston, & Langer-Osuna, 2008; Matusov, 1996; K. O'Connor, 2003). We take this approach here as well, recognizing that as ways of being, knowing, and doing are enacted, they will come into conflict and require ongoing negotiation. These relationships of power are not stable. They can shift and change since there are, in Foucault's (1999) words, "many points of resistance." (p. 477).

If we re-examine our classroom example from this phronetic stance, Denise and Emma addressed an actual problem (not understanding what they think are two theories offered by Rosie's and Rich's group) using practical wisdom that reflected a powerful scientific way of knowing (Emma initiates and then Denise persists with a line of questioning about alternative theories). This all happened in an ongoing social negotiation that was fluid and changing, that required moment-to-moment decisions and adjustments. Rich was trying to dissuade Denise from pursuing her line of questioning