Chapter 17
Situated Cognition and Cognitive Apprenticeship Learning

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Abstract This chapter presents approaches to situated cognition and cognitive apprenticeship learning. It pertains to "learning science," a theory that explains how learning happens in the context of learners working together with a specialist, master, or coach in an environment. Empirical and theoretical developments in learning sciences have led to the emergence of situated cognition, which assumes that cognition is fundamentally a social activity and is distributed across members of a learning community and that knowledge is situated in social, cultural, and physical contexts in which it is produced and used (Brown, Collins, Duguid in Situated cognition and the culture of learning 18(1):32–42, 1989; Lave and Wenger Situated learning: Legitimate peripheral participation, Cambridge University Press, 1991). Cognitive apprenticeship learning reflects situated learning theory (Collins, Brown, Holum in Cognitive apprenticeship: Making thinking visible 15(3):6–11, 38–46, 1991; Rogoff in Apprenticeship in thinking: Cognitive development and social context, Oxford University Press, 1990). The notion of apprenticeship has been influential in teaching and learning throughout history. Nonetheless, in education, there has been a move from traditional apprenticeship to cognitive apprenticeship. Focusing on cognitive skills and process rather than only physical skills development, using skills in varied contexts rather than only the context of their use, and using structured rather than entirely naturalistic opportunities for skill development differentiate cognitive apprenticeship from traditional apprenticeship. In this chapter, we report four dimensions of cognitive apprenticeship for designing a learning environment: content,

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method, sequencing, and sociology (Collins, Brown, Holum, in Cognitive apprenticeship: Making thinking visible 15(3):6–11, 38–46, 1991). This chapter also presents a framework of cognitive apprenticeship learning that includes six processes teachers would use to promote student learning: modeling, coaching, scaffolding, articulation, reflection, and exploration (Collins, Brown, Holum in Cognitive apprenticeship: Making thinking visible 15(3):6–11, 38–46, 1991). In this chapter, we framed design thinking methodology from a cognitive apprenticeship perspective with these four dimensions and six processes of cognitive apprenticeship learning (Brown in Change by design: How design thinking transforms organizations and inspires innovation, Harper Collins, 2009; Cross in Design thinking: Understanding how designers think and work. Oxford: Berg. Dewey, J. (1938). Experience and education. New York: MacMillan, 2011). We believe that pedagogical practices of cognitive apprenticeship and strategies like design thinking (Cross in Design thinking: Understanding how designers think and work. Oxford: Berg. Dewey, J. (1938). Experience and education. New York: MacMillan, 2011) would help teachers to make key aspects of thinking visible to students (Cakmakci in Australian Journal of Teacher Education 37:114–135, 2012; Collins, Brown, Holum in Cognitive apprenticeship: Making thinking visible 15(3):6–11, 38–46, 1991). Besides, avenues of how new technologies like Artificial Intelligence (AI) would facilitate situated cognition and cognitive apprenticeship learning need further exploration.

17.1 Introduction

Throughout the educational literature, there has been a shift from the behaviorist to constructivist theories of learning (Aikenhead, 1996). Besides, there has been a substantial shift from radical to social constructivism theories of learning within constructivist theories of learning. Accordingly, these theories have been influential in the design of several curricula. For instance, in countries like Germany, France, Switzerland, and South Korea, with dual education systems, people engage in many apprenticeship occupations (e.g., carpenter, dentist's assistant, electrician) in collaboration between companies/industries and schools. The dual education system is seen as an effective system, in particular in vocational schools, for creating a fourth industrial revolution (often called industry 4.0) ecosystem (Leopold, Ratcheva, & Zahidi, 2016) and also for promoting participants' social and emotional skills (OECD, 2017). In the U.S., constructivist views of learning have also dominated the discussion around curriculum development efforts in science and mathematics education. With the publication of the National Science Education Standards in 1996 and the Next Generation Science Standards (Achieve Inc., 2013) in 2013, more emphasis has been placed on students' participation in authentic scientific practices such as inquiry, modeling, and argumentation. Students' effective and meaningful participation in such practices can best be guided and interpreted through situated cognition and cognitive apprenticeship learning theories.

This chapter discusses situated cognition and cognitive apprenticeship learning, which are situated within social constructivist approaches to instruction. More specifically, we focus on the contributions of Brown, Collins, and Duguid (1989) and Collins, Brown, and Holum (1991) to the establishment and evolution of these theories and their relevance for reform efforts in science education.

According to situated learning theory, learning is a social activity that occurs when someone does something in a social context; the learning environment has social, cultural, and physical contexts (Brown et al., 1989; Lave & Wenger, 1991; Vygotsky, 1978). Cognitive apprenticeship learning reflects situated learning theory (Collins et al., 1991; Rogoff, 1990). The notion of apprenticeship has been influential in teaching and learning throughout history. Children learn their first languages from their families; novices learn how to grow crops, make houses, do farming, and cook; employees learn job skills; and scientists discover how to conduct research by working with seniors. Cognitive apprenticeship encourages learners to adopt the cognitive processes and skills of legitimate participants of a particular community through scaffolding. Therefore, cognitive apprenticeship suggests that the learning environment should be designed to make targeted cognitive processes explicit and visible so that students can observe, enact, and practice them in contexts that make sense to them and enhance their domain-specific and domain-general knowledge and skills.

17.2 Situated Cognition

Educational scientists have used learning theories to understand how learning takes place, how knowledge and skills are acquired, and how these knowledge and skills are used in different contexts. Empirical and theoretical developments in learning sciences have led to the emergence of situated cognition (Brown et al., 1989; Collins & Greeno, 2010Smith & Semin, 2004), whose main argument assumes that cognition is fundamentally a social activity and is distributed across members of a learning community and that knowledge is situated in the contexts, cultures, and activities, in which it is produced and used (Clancey, 1997; Robbing & Aydede, 2009; Roth & Jornet, 2013; Wilson & Myers, 2000). Two other assumptions of situated cognition theory are that (i) "cognition arises in, and for the purpose of, action, thus cognition is enacted" and "cognition is distributed across material and social settings because of features" (Roth & Jornet, 2013, p. 2); and (ii) *cognition becomes distributed when* a team of people engages in solving a problem through talk, questioning, and coordination of cultural and representational tools (Hutchins, 1995). These assumptions of situated cognition are rooted primarily in *Cultural Historical Activity Theory*, which considers "thinking, acting (praxis), and environment as interacting and dependent parts of the same analytic unit" (Roth & Jornet, 2013, p. 2).

In the 1980s, Brown et al. (1989) published one of their most influential seminal works, *Situated Cognition and the Culture of Learning*. Since this publication, the impact of the situated cognition perspective on learning has influenced many fields ranging from education, social psychology, communication, and computation. Yet, the social cognition perspective has had a tremendous impact on the field of education. According to situated learning theory, learning arises from the dynamic interaction between the learner and the environment in which the learning occurs (Roth & Jornet, 2013). Therefore, scholars researching this domain have focused on learners' actions concerning their cognition in a specific social, cultural, and physical context instead of taking learners' mental processing of information as the sole unit of analysis (Roth & Jornet, 2013). One of the main contributions of situated cognition to the field of learning is that "perceiving, remembering, or reasoning are not independent phenomena—to be explored as operations of the brain alone—but are integral to agents-in-their-context-acting- for-a-purpose-and-with-tools." (Roth & Jornet, 2013, p. 473). In science education, these assumptions have become instrumental in understanding what and how students learn science in authentic scientific contexts. For instance, situated cognition can help us explain how students may be able to appropriate the goals, epistemologies, and practices of scientists as they learn science.

Lave (1991) located cognition in practices, rituals (patterned actions) that are specific to particular cultural communities, and learning as a process of legitimate peripheral participation (Lave & Wenger, 1991) in these patterned actions and of cognitive apprenticeship (Lave, 1988). This is a radical shift from traditional views of cognition, where learning is viewed as acquiring knowledge through information processing and constructing mental representations of the external world. This new perspective views learning "in terms of expanding the learner's action possibilities in larger systems of activity" (Roth & Jornet, 2013, p. 4) rather than limiting learning to cognitive phenomena solely to encoding, retrieval, or information processing. Language and other cultural tools of practice play a crucial role in this new perspective on learning. According to situated cognition, "language is not a system of correspondences between symbols and elements in the world, but a means for humans to coordinate their situated actions with others and for agents to stimulate their own minds" (Roth & Jornet, 2013, p. 468). From a situated cognition perspective, "cognitive phenomena are not restricted to what happens inside the brain, but refer to the interactions within the person-in-situation unit" (Roth & Jornet, 2013, p. 468), often via language.

If teaching practices and methods were viewed as an evolutionary timeline, most of the timeline would be dominated by what is commonly referred to as conventional teaching methods. These are the methods that many of us experienced in school, such as lectures, presentations, note-taking, memorization practices, techniques, worksheets, and many more. These conventional teaching methods take on multiple manifestations in the classroom but share the common characteristics of teachers somehow being in charge of transferring required knowledge to students. This experience contradicts how science is practiced and how scientific models are constructed, evaluated, and critiqued in authentic scientific contexts.

These conventional teaching practices are more recently referred to as the "Banking" model of education, based on the writings of Paulo Freire. Freire (2005) used the term "Banking" to intentionally show that teachers were in control of depositing information into students, and students were thus passive (and thus in a power-negative and oppressive situation) in the learning process. Freire argued for liberating educational practices, namely, educational practices that empower instead of oppress students. Freire proposed multiple methods of achieving liberating education, including allowing students to construct their learning by recognizing the cultural capital of students and the context in which the learning takes place as essential to the learning process.

Freire's concepts are often combined with the works of Dewey and Piaget to form the basis for a modern constructivist model of education. Piaget, usually called the father of constructivism, tirelessly promoted the importance of human experiences and the learning process. Dewey echoed these calls, especially in the realm of science, by encouraging laboratory experiences in the sciences to promote real-world learning experiences and problem-solving skills.

Research on educational methodology based on the theoretical frameworks of Freire, Piaget, and Dewey is now commonplace. The past 50–75 years on our educational timeline show a clear shift from the conventional banking model of education toward the various methods that a constructivist and/or liberating education construct can manifest in a teaching and learning environment. An examination of this research shows two related yet distinct veins of investigations: research into the social interactions and contexts of the educational process (related mainly to Freire's concepts of liberating education) and research into the cognitive and conceptual processes and procedures of knowledge acquisition (related mainly to constructivist theories of education).

Situated cognition (also called situated learning) recognizes the importance of overlapping these two research veins and theoretical frameworks. As defined by Collins and Greeno (2008), situated cognition is "the view that knowing and learning by individuals are inextricably situated in the physical and social contexts of their acquisition and use" (p. 335). Vosniadou, Loannides, Dimitrakopoulou, and Papademetriou (2001) explain the situationality of knowledge by stating, "students do not come to school as empty vessels but have representations, beliefs, and presuppositions about the way the physical world operates" (p. 392). Brown et al. (1989) further elaborate that all knowledge is situated not just in the teaching and learning process but also in the "context and culture in which it is developed and used" (p. 32). This has significant implications for science education. Scientific practice, its goals, epistemologies, the knowledge it produces, and the process that leads to the production of that knowledge are not only context-driven but also influenced by the sociocultural practices of the community in which it is being practiced.

If students were empty vessels, no knowledge construction would be needed; we could simply fill the empty vessel with knowledge. Instead, effective science instruction must recognize that culture and society frame both the knowledge students possess upon entering school and the knowledge and skills they are expected to obtain once in the classroom setting.

To understand the role of situated cognition in education and research, we need to clarify what is meant by the terms knowledge, the role of context in learning, social context, cultural context, physical context, and activity.

17.2.1 Knowledge

Situated cognition recognizes that "knowledge is social, and no other knowledge is more social than any other" (Khan et al., 1998, p. 772). Examples of this viewpoint of knowledge abound, including Brown et al.'s (1989) description of language acquisition. Brown et al. (1989) point out that while dictionaries are valuable resources, we do not teach children to read, write, and speak by sitting them down in front of a dictionary. Language acquisition cannot happen by an individual alone, even with valuable resources; acquiring the knowledge of using and understanding a language is a social event that requires multiple interactions between several individuals in the social system.

Given the social nature of knowledge, we can also see that knowledge is contextual. If learning is social, that means that all learning has a social context, and thus, all learning is contextual. Brown et al. (1989) explain the contextual nature of knowledge by pointing out that the jargon, slang, accent, and even the language a child learns to use depends directly on the cultural context where their socially dependent learning occurs.

Finally, recognizing that knowledge is both social and contextual, one can naturally ask how to take this social and contextual knowledge and transition it into the more specialized body of knowledge required by many scientists. Children may learn to read, write, and communicate from the social interactions driven by the rich cultural tapestry where they spend their formative years. However, how do these children socially and culturally learn the knowledge and skills necessary to perform surgery, conduct research, or engineer technological improvements? For this explanation, we look to the concept of cognitive apprenticeship (Collins, Brown, & Newman, 1987), which will be discussed later in this chapter.

17.2.2 Role of Context in Learning

Now that we understand how knowledge is defined, we will look closely at the essential component of situated cognition: that knowledge is "inextricably situated" in context (Collins & Greeno, 2008). Situated cognition recognizes several contexts closely linked to knowledge acquisition and use, including social, cultural, and physical contexts. While we want to emphasize that these contexts are all interrelated, we now look at them individually to examine the unique applications to science education of each context type.

17.2.3 Social Context

In addition to recognizing the role of social interactions in the learning process, situated cognition recognizes that the social constructs and identities of the members of a community of learners impact the learning process (Gee, 1997). Of particular interest to science educators is the role of social identity and how that contributes to the social context of learning science. Social identities have been shown to directly impact both achievement in science and motivation to pursue science higher education and careers. One example is that students with female gender identity are often less likely to pursue science fields in higher education and/or careers in the sciences (Aydeniz & Hodge, 2011; Carlone & Johnson, 2007). Identity development as females in a social context that promotes males as the dominant learning group of scientists perpetuates this participation gap. Tan et al. (2013) observed that when the school classroom environment is not supportive of identity-based learning, female students who had previously expressed interest in science lost interest or distanced themselves from pursuing higher science education. Riedinger (2015) found that youth derive their sense of self and identity from perceived membership and belonging in a learning group. Thus, negotiating and developing one's identity as a member of the learning group, such as female science students needing to navigate social roles and power dynamics unique to female science students, are essential to science learning. The importance of female science students needing to navigate identity development in the science classroom is only one example of social context and its impact on science learning. In a social context where females were not statistically shown to participate in science careers at much lower rates than their male counterparts, or in a social context where textbooks and other learning media did not over-represent males as practitioners of science, the role of identity development in science learning for female students would not be of much concern. It is the role of a practitioner of situated cognition to identify the social contextual factors unique to their learning environment and recognize these as a part of daily practice.

17.2.4 Cultural Context

Brown et al. (1989) place such importance on the cultural context of learning that they create a term for this: "enculturation" (p. 33). While it is easy to understand how a child's language acquisition (to refer to our earlier example) depends on the cultural context in which learning occurs, many struggle to see how this concept applies to science learning. Science taught in schools often minimizes or leaves out entirely the cultural context of the scientific understanding in favor of the scientific facts as they are currently understood and explained. Thus, when scientific knowledge is a product of new technology or new research, many science students are left behind, clinging to their notions of science as they learned them in school based on the misguided misunderstandings that science is universally above cultural influence.

Recognizing the cultural context of learning as provided by the situated cognition framework is especially helpful to science teachers as a method to prevent these common misconceptions regarding the nature of science.

17.2.5 Physical Context

The physical context of where learning occurs is often seen as troublesome from the situated cognition standpoint. While Dewey (1938) successfully implemented more experiential learning in the sciences through additions of laboratory activities, more recently, we have questioned the authenticity of these science learning experiences. The idea that students must engage in practices standard to their subject area and learning experiences that are meaningful to the social and cultural world outside of school is often referred to as authenticity.

Brown et al. (1989) point out that school activities are inherently inauthentic for several reasons: (1) often school activities do not incorporate the social and cultural aspects of learning, as discussed above, making them inauthentic learning experiences, (2) the practices taught and expected in school are not the practices expected by experts or practitioners in the field, and (3) even if a school or teacher attempts to address either or both #1 and #2, the culture of the school and the classroom context often overshadow these attempts, creating at best a "hybrid" learning activity rather than an authentic learning activity (p. 34). In addition to promoting the benefits of authentic learning, Brown et al. (1989) caution that inauthentic school activities and assignments lead to ineffective learning, stating that these inauthentic environments "create a culture" of "phobia" for the subject area being presented. (p. 34). Echoing Brown et al.'s sentiments, Bricker and Bell (2014) state that school can be disruptive to science learning, specifically that the formality of the classroom setting is not conducive to a learning pathway that considers culture and identity as an aspect of science learning (Aikenhead, 1996). As creating a phobia or lack of motivation toward science is not the goal of any conscientious science teacher, special attention must be allocated to the contextual authenticity of learning experiences in the science classroom.

We must also recognize that the physical context of learning—where the learning takes place—largely depends on the social and cultural context of learning. School quality, both in teacher quality and availability of resources, varies widely based on the socioeconomic level and cultural respect for education in science education. From the situated cognition standpoint, there is undoubtedly potential for place-based learning and out-of-school learning to provide more authentic learning experiences than in a school classroom. However, science educators will eventually need to correct and adjust the classroom climate to provide more authentic, socially, and culturally contextual science education experiences. Relying on experiences out of school to correct for the lack of situated cognition in school is shortsighted at best and, at worst, discriminatory toward those who cannot attend the out-of-school experiences.

17.2.6 Activity

From the situated cognition standpoint, we have discussed the nature of knowledge and the contexts in which this knowledge occurs (or does not occur, as the case may be). There is one more component of situated cognition to discuss: the activity of learning. All learning or attempted learning is an activity. Brown et al. (1989) forcefully attest that "the activity in which knowledge is deployed… is not separable from or ancillary to learning and cognition. Rather, it is an integral part of what is learned" (p. 32).

Fortunately, learning activities are best suited for science education, and situated cognition abounds. In recognition of the need for meaningful, practitioner-based activities, science education offers problem and project-based learning, modeling, visualization, argumentation, collaborative learning, questioning, forecasting, labs, experiments, etc. The role of the teacher in the science classroom is often creating, selecting, preparing, and delivering these activities for their students. Many resources are available to teachers in the quest to select activities that will lead to knowledge. However, science educators must remember that "different ideas of what is appropriate learning activity produce very different results" (Brown et al., 1989, p. 32). This means that the activity you acquire from a science educational supplier might work one year and not the next. Or an activity you received from a colleague in a school across town might have been magical for their classes but a total failure for your class. Or, that list of labs that all science teachers in your district are supposed to complete with fidelity to the instructions—well, probably not all of them will be successful in your classroom. Why? According to situated cognition, activity is integral to learning, and learning is dependent on context. Therefore, the learning successes of classroom activities vary according to the classroom's social, cultural, and physical contexts. The role of the effective science teacher is not just selecting authentic activities as good learning experiences but tailoring and executing these activities based on their professional knowledge of the unique contexts within and surrounding their classroom and their curriculum goals.

Given the complexities that are now apparently involved with becoming a science teacher practitioner of situated cognition, there is no list of lesson plans or labs we can distribute as examples of situated cognition in the science classroom. Examples exist, yet these examples are often discussed in the context of the features they contain rather than a step-by-step implementation plan for use in the school. This lack of demonstrability leads to the rift between the theory of situated cognition and the implementation of the tenets of situated cognition in the classroom. To help bridge this rift, we offer the following reminders for those looking to promote situated cognition in the science classroom:

- The traditional banking model of education offers limited opportunity for situated learning to occur;
- Knowledge and learning are socially, culturally, and contextually situated. Promotion of identity development alongside science learning is vital to addressing the social context of science learning;

- Ignoring the cultural impact on science will not promote an accurate conception of the nature of science;
- School settings have the potential to be detrimental to authentic science learning activities;
- While no activity is fail-safe in all educational contexts, the activity chosen must allow students to construct their own knowledge; and
- The individual responsible for tailoring instruction to meet the needs of all learners by selecting appropriate learning activities and recognizing the social and cultural components of science learning within those activities is ultimately the science teacher.

17.3 Cognitive Apprenticeship

Cognitive apprenticeship is essential in describing children's cognitive and social growth. Rogoff (1990) argues that children's development is an apprenticeship in nature. Children are guided to participate in social activity within the social community, which supports their understanding of the cultural norms of the social group and the development of skills in using the tools of the culture to which they belong. Teaching and learning have been based on apprenticeship with a different emphasis throughout history. Nonetheless, in education, there has been a move from traditional apprenticeship to cognitive apprenticeship. A focus on cognitive skills and process rather than only physical skills development, the use of skills in varied contexts rather than only the context of their use, and the use of structured rather than entirely naturalistic opportunities for skill development differentiate *cognitive apprenticeship* from *traditional apprenticeship* (Collins et al., 1991). When we teach science, we are enculturating students into the community of scientists and expect them to acquire epistemology, knowledge skills, ways of thinking, and tools of the scientific or engineering community.

Collins et al. (1991) suggested four dimensions to consider while designing a learning environment based on cognitive apprenticeship learning: *content*, *method*, *sequencing*, and *sociology*. In addition, they also suggested a pedagogical framework that included six processes teachers would use to promote student learning: *modeling*, *coaching*, *scaffolding*, *articulation*, *reflection*, and *exploration.* In this chapter, we framed design thinking methodology from a cognitive apprenticeship perspective with these four dimensions and six processes of cognitive apprenticeship learning (Brown, 2009; Cross, 2011). We believe that, as represented in Fig. 17.1, pedagogical practices of cognitive apprenticeship and strategies like design thinking (Cross, 2011) would help teachers to make key aspects of thinking visible to students (Cakmakci, 2012; Collins et al., 1991).

Fig. 17.1 In the first picture, two learners carry out a task from a real-world context. In the second picture, the teacher facilitates their learning by explicitly discussing vital scientific concepts and practices in the task. *Photograph* © Gultekin Cakmakci

17.4 Design Thinking from a Cognitive Apprenticeship Perspective

Humans have been designing since antiquity using various approaches depending on the task. Design thinking is a method of solving problems in a practical, creative, iterative way that can be applied in different domains (Cross, 2011). In this method, one begins by identifying the need or problem, then proceeds with understanding the context within which a solution is implemented and tested, and then refined by incorporating user feedback. This exemplifies the cognitive apprenticeship theory, given that learners encounter authentic tasks and real-life situations, interact with skilled instructors and coaches to learn domain-specific and domain-general skills, focus on cognitive rather than only physical skill development through deliberately planned activities, and use methods that scaffold learning. The result of applying design thinking, a hands-on learning method, is that students are likely to understand better, internalize, and apply learned concepts. The hands-on nature also lends itself to science teaching and many other domains. This approach allows learners to encounter concepts within real-world settings where they observe and enact solutions with the help of their instructors—who scaffold the learners as they practice their skills. These concepts may span different disciplines (Brown, 2009), from physics, material science, anthropology, biology, psychology, and others, which together form the basis of solutions to problems ranging from tasks such as creating a better electronic device to designing a modern patient care facility that takes advantage of cutting-edge technology. Using this method, students can develop different ways of applying the knowledge and skills gained from learning activities while interacting with their instructors, then crafting solutions and, at times, generating novel ideas. They make sense of their scientific knowledge within the given contexts by interacting and understanding their users in a real-world setting—and solving real-world problems with help from experts—which fosters a higher level of learning and mitigates issues around authenticity, context, and thought processes (Brown et al., 1989) expected to other styles. A brief case study using a project-based college class illustrates this learning method.

In one such year-long class that employs design thinking—in the engineering department of Stanford University (ME310 Design Methodology)—novice product design students are presented with complex problems from different industries and of varying specifications from open to very narrow prompts and asked to craft solutions. For instance, the tasks may vary from designing the next-generation space shuttle for a leading aeronautics company to developing a single detailed feature of an intelligent building to be constructed overseas. To successfully solve such tasks, students have to understand the context—physical, social, and conceptual—within which they are working and the relevant tools and technologies available within these contexts. These examples demonstrate the in-context nature of the learning environment, where the students explore the problem space to understand their intended users and their corresponding needs, followed by idea generation based on what they have learned from interaction with these users, and finally, applying their science skills to create tangible solutions. The process is iterative since new insights from users often lead to a point of view that might inspire ideas that, once prototyped, point to other new ideas and may even require a new round of observations to understand new aspects—which may have been previously disregarded or were deemed insignificant.

As for the cognitive process, these ME310 students engage with multiple stakeholders under the guidance of their instructors and coaches, learning by doing actual design work despite their limited experience in the industries they engage with while creating knowledge, exploring new concepts, and immediately applying new knowledge to their designs. Therefore, this apprentice model presents both the maker aspects and the cognitive apprenticeship characteristics through engaging with design tasks under the supervision of experienced faculty members and industry professionals. Another essential feature of this program is the industry partnership from which one or more corporate personnel are provided to engage with each ME310 team working on their task actively. They often bring extensive knowledge, skills, and connections with the corporate entities that might be interested in the outcome, adding yet another resource for the students. These corporate liaisons act as sounding boards for the students' ideas and guide them as they visit actual industries, users, and spaces, allowing them to investigate every critical aspect of their task.

Students in the ME310 class come in as novices and transform within a year to accomplished engineering designers with a tangible product developed under the guidance of specialists from whom they learn along the way while also creating new knowledge by combining different aspects of their experience. This learning experience can be simplified into three general, distinct steps: understanding the process, practicing the process, and delivering a target solution. In each of these steps, students are guided as they explore, discover, and apply new knowledge in solving complex problems under the supervision of their instructors and coaches. We can, therefore, view design thinking within three broad aspects under this framework: understanding, practicing the process and delivering solutions.

17.4.1 Understanding the Process

This first stage involves getting the students to understand the design thinking methodology and equipping them with the basic skills required to conduct user research effectively to understand the context within which their problem and solution lie. It takes advantage of learners' curiosity toward science, people, and their interactions with their surroundings, effectively providing the contextual setting.

17.4.2 Practicing the Process

Once the students get the general ideas around design thinking, they are presented with fast-paced tasks to familiarize them with the concepts. They may be asked to identify a problem (discover a need) within a specific space, propose solutions, and test them to determine if they fit. This process is often fast-paced to give the students a chance to explore multiple possibilities instead of concentrating on perfecting a single idea. One common introductory task is building "paper bikes"—something that few, if any, of incoming students have ever done before, allowing them to explore their creative imagination and to employ the many science skills and knowledge they already possess. Beyond this, they engage with designated industries to begin exploring their long-term project such that subsequent prototypes reflect identified problems/needs within their space.

17.4.3 Delivering Solutions

The student teams are each sponsored by a corporate entity. While they are composed of students from two to three universities from around the globe, they work with and learn from all instructors and eventually deliver a finished product to their sponsor. Given that different schools offer different areas of specialization, the instructors, coaches, and partners ensure that each team leverages their differences—for example, industrial design, mechatronics, and manufacturing in one team. They use their knowledge and skills to design, fabricate parts, assemble their prototype, and test and improve it using feedback from their intended users. The final product is manufactured once testing is complete and modifications have been made to reflect feedback. Some researchers argue that in some cases, entrepreneurship or impact aspects could be added or explicitly addressed in the design thinking model. This ME310 example presents a brief overview of the design thinking method in practice. It includes a summary of the activities highlighting different aspects and processes to demonstrate how they are implemented in one university course. While many unique elements make the course an excellent fit for this method, educators in other settings may find their own ways of implementing this model of cognitive apprenticeship within their specific situations. Let us now consider the above process in terms of the dimensions for designing a learning environment (Collins et al., 1991) and how instructors promoted student learning in ME310.

17.5 Dimensions of Cognitive Apprenticeship for Designing a Learning Environment

Collins et al. (1991) suggested four dimensions to consider when designing a learning environment based on cognitive apprenticeship learning: content, method, sequencing, and sociology. Using the ME310 class example, we see these dimensions embodied in the different components of the learning space. Let us explore each, followed by processes applied to support learning.

- *Content*: The content incorporated real-life examples and scenarios that were used to model skills and generate the tasks assigned to student teams.
- *Method*: Learning was hands-on, iterative problem solving, scaffolded by instructors and coaches, allowing learners to gain and practice new skills with expert support.
- *Sequencing*: The learning activities and tasks were deliberately planned to advance mastery by presenting just the right level of difficulty on subsequent tasks.
- *Sociology*: Learning in this class was inherently cooperative, with students learning from and interacting freely with each other, instructors, coaches, and potential users of their products.

17.6 Six Processes Used in Promoting Student Learning

17.6.1 Modeling

The instructors and coaches in ME310 begin with learning activities that allow them to model the skills as they invite students to participate through assigned tasks, such as making observations, asking questions, annotating, and others.

17.6.2 Coaching

Once students begin working on assigned tasks, the instructors and coaches monitor and provide directions as necessary, pointing out opportunities for best performance and successful completion of tasks. This could be as simple a task as assigning responsibilities within a team or setting up a shared planner/timeline.

17.6.3 Scaffolding

The instructors continue to monitor learning while providing specific help, directions, and opportunities to perform advanced tasks once students demonstrate mastery or revisit previously covered skills if necessary. An example is asking students to create multiple variations of a prototype for an extra score.

17.6.4 Articulation

Students learn from instructors and coaches who verbalize their thought processes and describe the interconnectedness of different aspects needed to complete tasks. For instance, the instructor may explain what constitutes significant user testing.

17.6.5 Reflection

Once students have completed a specific task, such as interviewing a user or assembling a prototype, they reflect on the process verbally or in writing. They share this with their team and instructors.

17.6.6 Exploration

The students are encouraged to go beyond the examples presented by imagining new scenarios as they seek to understand and resolve problems. This is where novel ideas emerge—such as designing a manufacturing platform to invent the future space shuttle—something that would have seemed far removed from the initially assigned task.

17.7 Conclusion

In this chapter, we discussed two fundamental learning theories, situated cognition and cognitive apprenticeship learning, which are situated within social constructivist approaches to instruction. We also supported our discussion with a case study in which engineering design was looked at and implemented through a cognitive apprenticeship perspective. While situated cognition and cognitive apprenticeship have contributed to our understanding of learning, the characteristics of emerging learning contexts and tools have made using these two theories more relevant than ever. According to situation learning theory, learning arises from the dynamic interaction between the learner and the environment in which the learning occurs (Roth & Jornet, 2013). Thus, any interpretation of learning should acknowledge the social, cultural, and historical context in which learning occurs. These two theories suggest that learning is not only about memorizing and retaining knowledge but also about becoming someone, belonging to a culture, and learning how to become a legitimate, competent, and productive group member. This requires knowing how to use the rules, tools, and norms of the specific culture in which one tries to achieve legitimate membership (Lave & Wenger, 1991). Accordingly, learners' social and emotional skills are also central to this process (OECD, 2017). Science education colleagues have studied how students learn when the learning tasks are designed based on cognitive apprenticeship, and the learning contexts emulate authentic scientific contexts (Barab & Hay, 2001; Charney et al., 2007). The findings suggest that students develop more robust and meaningful under-standings and acquire a deeper understanding of the nature of science (Bell, Blair, Crawford & Lederman, 2003).

Collins et al.'s (1991) emphasis on four dimensions such as *content*, *method*, *sequencing*, and *sociology,* need to be considered while designing a learning environment and must be taken very seriously by educators as they create learning environments in and outside of classrooms. Applying these dimensions in the design of learning environments will result in more productive student engagement. However, making learning relevant to students' lives and considering context and culture will make learning more authentic. This implies that the goals of our learning activities should focus on epistemologies of science, engage students in deep questions related to the nature of science, and the activities we design should engage students in such practices as modeling, argumentation, and questioning, the types of practices that are used to construct, justify, evaluate, critique, and validate the scientific knowledge. When it comes to practical applications and limitations of this theory, the blended and online learning platforms, as well as online instructional videos—where learners engage with a trainer in isolation (mostly) rather than within a direct, personal, social setting—contrasts the theory and suggests a different approach. The online learning video scenario thus limits the application of this theory, as some of the parts that make up the theory are missing. Hence, online learning platforms need to improve their approaches in that sense.

Reflections for Readers

The following questions would be considered for future research:

- In what ways do new technologies like Artificial Intelligence (AI) facilitate situated cognition and cognitive apprenticeship learning?
- How would situated cognition and cognitive apprenticeship learning theories guide the development of AI-powered tools such as simulated learning environments, augmented reality (AR) and virtual reality (VR) systems, natural language processing (NLP) platforms, coaching/mentoring platforms, and personalised assessment and learning systems?

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