Pedagogical Content Knowledge and Industrial Design Education

Kenneth R. Phillips, Michael A. De Miranda, and Jinseup "Ted" Shin

Abstract

Pedagogical content knowledge (PCK) has been embraced by many of the recent educational reform documents as a way of describing the knowledge possessed by expert teachers. These reform documents have also served as guides for educators to develop models of teacher development. However, in the United States, few if any of the current models accurately address the role of PCK in the development of industrial design educators. This article introduces the concept of PCK and how a taxonomy of essential industrial design subject matter can be organized to serve as a content guide. The PCK model presented could serve as a catalyst for the field of industrial design education to produce a conceptual framework and taxonomy for the teaching of industrial design upon which future PCK studies in industrial design education can be based. These conceptual frameworks (or taxonomies) help within a field to articulate the core knowledge, skills, and dispositions that define practice. The interaction of teacher content knowledge in industrial design, pedagogical knowledge, and context of industrial design is framed within a PCK taxonomy.

Introduction and Background

Theoretical Framework

The notion of pedagogical content knowledge (PCK) was first introduced to the field of education by Lee Shulman in 1986 and a group of research colleagues collaborating on the Knowledge Growth in Teaching (KGT) project. The focus of the project was to study a broader perspective model for understanding teaching and learning (Shulman & Grossman, 1988). Members of the KGT project studied both how novice teachers gained new understandings of their content and how these new understandings interacted with their teaching. The researchers of the KGT project described PCK as the intersection of three knowledge bases coming together to inform teacher practice: subject matter knowledge, pedagogical knowledge, and knowledge of context. PCK is described as knowledge that is unique to teachers and separates, for example, an industrial design (ID) teacher/professor from a practicing industrial designer. Along the same lines, Cochran, King, and DeRuiter (1991) differentiated between a teacher and a content specialist in the following manner:

> Teachers differ from biologists, historians, writers, or educational researchers, not necessarily in the quality or quantity of their subject matter knowledge, but in how that knowledge is organized and used. For example, experienced science teachers' knowledge of science is structured from a teaching perspective and is used as a basis for helping students to understand specific concepts. A scientist's knowledge, on the other hand, is structured from a research perspective and is used as a basis for the construction of new knowledge in the field (p. 5).

Geddis (1993) described PCK as a set of attributes that helped someone transfer the knowledge of content to others. According to Shulman, it includes "most useful forms of representation of these ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1987, p. 9).

In addition, Shulman (1987) suggested that PCK is made up of the attributes a teacher possess that help her/him guide students towards an understanding of specific content, such as industrial design, in a manner that is meaningful. Shulman argued that PCK included "an understanding of how particular topics, problems, or issues are organized, presented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (1987, p. 8). In light of what industrial design educators should know and be able to do, Shulman (1987) might assert that PCK is the best knowledge base of teaching and suggested:

> The key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are

> pedagogically powerful and yet adaptive to the variations in ability and background presented by the students (p. 15).

Therefore, the intersection of industrial design content knowledge and the pedagogical knowledge of industrial design instructors, depends on the ability of design educators to transform this knowledge into a design rich adaptive instruction that unifies these elements of PCK into successful instruction (Mishra & Koehler, 2006). Figure 1 helps to capture this complex relationship between content knowledge, knowledge of teaching, professional design context, and their interaction in an instructional setting.

Figure 1 helps to conceptualize the complex relationship between a teacher's content knowledge in industrial design in addition to knowledge required to infuse these concepts into classroom instruction. This knowledge combined with an instructor's general knowledge of pedagogy helps to contribute to a specialized form of pedagogical knowledge in industrial design education. In addition, the specialized knowledge of industrial design is often highly contextualized in the form of authentic application to design problems that are relevant to professional practice.

While content *knowledge* refers to one's understanding of the subject matter, and *pedagogical knowledge* refers to one's understanding of teaching and learning processes independent of subject matter, *pedagogical content knowledge* refers to knowledge about the teaching and learning of particular subject matter, taking into account its contextual learning demands. The rationale for doing this is appropriately suggested by Geddis (1993):

> The outstanding teacher is not simply a 'teacher,' but rather a 'history teacher,' a 'chemistry teacher,' or an 'English teacher.' While in some sense there are generic teaching skills, many of the pedagogical skills of the outstanding teacher are content-specific. Beginning teachers need to learn not just 'how to teach,' but rather 'how to teach electricity,' how to teach world history,' or 'how to teach fractions.' (p. 675)

Additionally, one could add, 'how to teach concept visualization skills,' or 'how to teach manufacturing processes,' or 'how to teach computer aided design.' Obviously, the demands of learning about concept visualization skills are different from the demands of learning about manufacturing processes. Good teachers are able to carefully analyze the various sorts of content-specific demands in each of these areas related to teaching industrial design.

Each industrial design educator has a unique knowledge of specific domains spanning multiple content areas based on his/her industrial experience. This professional experience is what informs quality instruction when

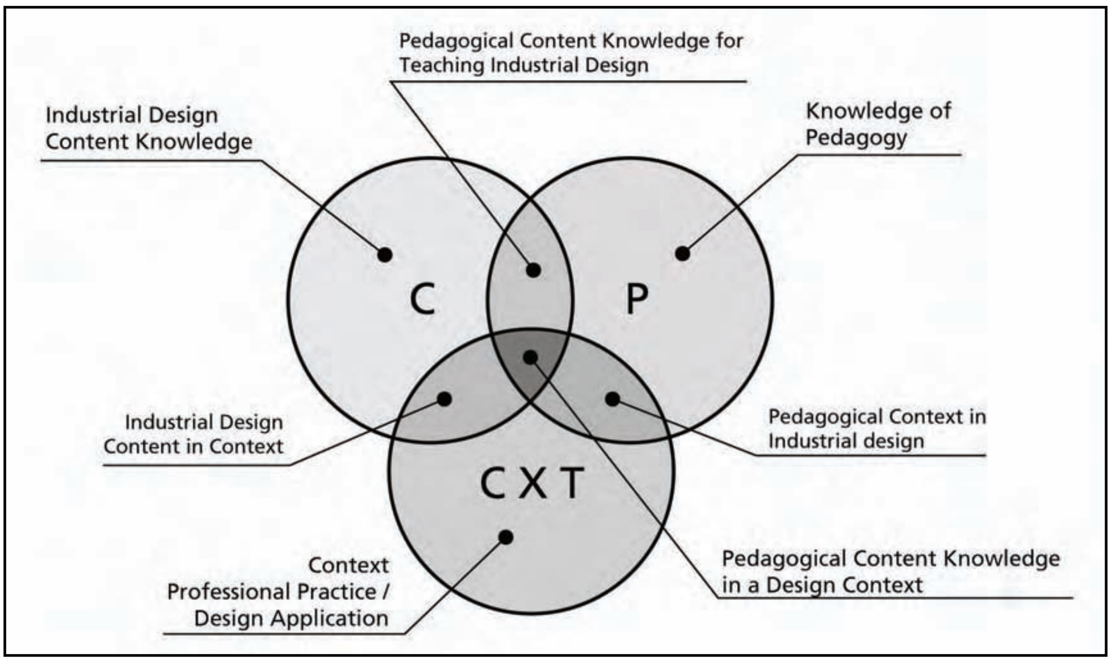

Figure 1. Model of content knowledge, pedagogy, and context in industrial design education.

combined with overall content knowledge and pedagogy. Quality design educators have come to know the subject matter in industrial design, not only for the content itself, but also in terms of its “teachability” and “learnability.” Shulman (1986, p.9) conceptualized these as the “transformation of subject-matter knowledge into forms accessible to the students.” The implications for this in terms of quality industrial design instruction will require this blending of content knowledge, professional design context, and knowledge of pedagogy. Geddis (1993) informed us that “in order to be able to transform subject matter content knowledge into a form accessible to students, teachers need to know a multitude of particular things about the content that are relevant to its teachability” (p. 676). Developing ways to do this is indeed the creation of new knowledge of a type that characterizes the good teacher, and it is part of her/his professional skill. The design education community must recognize the requirement for teachers to invent this new integrated knowledge.

The continued interest in PCK as an epistemological perspective in the preparation of industrial design educators may provide an opportunity to frame and guide the transition of industrial design professionals to becoming industrial design educators. The PCK model could serve as a catalyst for the field of industrial design education to produce a conceptual framework and taxonomy for the teaching of industrial design upon which future PCK studies in industrial design education can be based. These conceptual frameworks (or taxonomies) help within a field to articulate the core knowledge, skills, and dispositions that define practice (Travers, 1980).

PCK and the Training of Industrial Design Educators

Pedagogical content knowledge research and its implications for design education have important messages for the teaching and learning of industrial design and the infusion of design concepts into the curriculum. Commenting on criteria used for evaluation of teaching in the 1980s, Shulman (1986, p.5) asked, “Where did the subject matter go? What happened to the content?” Of course we should attempt to advance educational theory, in the same way that any other discipline does “pure research.”

But surely advances in theory of a discipline have only one purpose: to reflect back on, and improve, the practice of that discipline. Perhaps a productive path to travel is to examine more critically the concept of PCK and what it means or could mean to the preparation of future industrial design educators. In addition, examining the notion of PCK can inform an understanding of what is required to teach and infuse critical design concepts in the industrial design classroom. This will require those in the field of industrial design to move ahead of many technical fields in articulating a conceptual framework that supports a taxonomy of industrial design content knowledge; a task that may be close at hand.

Why Taxonomies and Conceptual Frameworks Matter in a PCK Model

Many have specific taxonomies to aid the understanding of PCK within the content area. For example, two explicit taxonomies are available in science education literature, and there is a framework in technology education literature that can help guide the emerging field of engineering and technology education in understanding the PCK required to deliver meaningful engineering content (McCormick & Yager, 1989; Neale & Smith, 1989, Lewis & Zuga, 2005). Shulman (2002) advanced a taxonomy of learning one can liken to the original work of Benjamin Bloom (1956) to extend a deeper understanding of learning. In each case, a taxonomy designed to organize content or concepts in a field helped to stir discourse and clarify learning and outcomes. Likewise there is a good base of research literature on the categories that should be taught in industrial design, yet there is no current taxonomy or framework developed to facilitate understanding the PCK required to prepare industrial design professionals to succeed as educators (Croston, 1998; NASAD, 2008; Yeh, 1999). The development of such a framework to guide what should be taught in industrial design education could provide a basis for informing a quality industrial design educator. The industrial design content literature and accreditation requirements like standards and content schemes in other fields may provide a starting point for the development of such a conceptual framework and essential knowledge hierarchy to benefit the field (Koehler & Mishra, 2008).

Accreditation and Guidelines for Industrial Design Education

The accrediting body in the United States for industrial design programs is the National Association of Schools of Art and Design (NASAD). NASAD is the only accrediting agency covering the field of art and design recognized by the U.S. Department of Education. NASAD provides basic criteria for member institutions, general standards and guidelines for all undergraduate degree programs in the visual arts and design, and standards and guidelines for specific professional degree programs, such as industrial design. Industrial design education involves a combination of the visual arts disciplines and technology, utilizing problem-solving and communication skills.

Specific NASAD standards and guidelines for industrial design programs include the following.

Curricular structure. Curricular structure, content, and time requirements shall enable students to develop the range of knowledge, skills, and competencies expected of those holding a professional baccalaureate degree in industrial design. Curricula to accomplish this purpose normally adhere to the following guidelines: studies in industrial design comprise 30-35% of the total program; supportive course in design, related technologies, and the visual arts, 25-30%; studies in art and design history, 10-15%; and general studies and electives, 25-30%. Studies in industrial design; supportive courses in design, related technologies, and the visual arts; and studies in art and design histories normally total at least 65% of the curriculum.

General studies. The NASAD standards provide guidelines for a well-rounded general education for industrial design education programs. Concepts and courses from the physical and natural sciences, the social sciences, and the arts and humanities are important for industrial designers. These guidelines provide the freedom for institutions to strengthen industrial design education by integrating courses and creating innovative interdisciplinary programs.

Essential competencies. The NASAD standards provide guidance in the essential or core knowledge competencies for industrial design education. This is perhaps the most informative component of the NASAD standards that can inform a framework that defines the content knowledge component of the PCK model. The knowledge competencies include the following:

(a.) A foundational understanding of how products work; how products can be made to work better for people; what makes products useful, usable, and desirable; how products are manufactured; and how ideas can be presented using state-of-the-art tools.

(b.) Knowledge of computer-aided drafting (CAD), computer-aided industrial designs (CAID), and appropriate two-dimensional and three-dimensional graphic software.

(c.) Functional knowledge of basic business practices, professional practice, and the history of industrial design.

(d.) The ability to investigate and synthesize the needs of marketing, sales, engineering, manufacturing, servicing, and ecological responsibilities and to reconcile these needs with those of the user in terms of satisfaction, value, aesthetics, and safety. Industrial designers thus must be able to define problems, variables, and requirements; conceptualize and evaluate alternatives; and test and refine solutions.

(e.) The ability to communicate concepts and requirements to other designers and colleagues; to clients and employers; and to prospective clients and employers. These communication skills include verbal and written forms, 2-D and 3-D media, and levels of detailing ranging from sketch or abstract to detailed and specific.

(f.) Studies related to end-user psychology, human factors, and user interfaces.

These essential competencies could serve the field as a catalyst for articulating the content knowledge that defines the core body of knowledge that interacts with pedagogy and context in the PCK model of understanding industrial design learning and instruction.

Essential opportunities and experiences. A unique feature of the NASAD standards guide is the inclusion of essential opportunities to learn and professional experiences. These areas are often neglected in other fields of study and could serve as a model for other technical fields. The essential opportunities to learn and experience include the following:

(a.) Opportunities for advanced undergraduate study in areas that intensify already-developed skills and concepts and that broaden knowledge of the profession of industrial design. Studies might be drawn from engineering, business, the practice and history of visual art, design, and technology, or interdisciplinary programs related to industrial design.

(b.) Easy access to computer facilities; woodworking, metalworking, and plastics laboratories; libraries with relevant industrial design materials; and other appropriate work facilities related to the major.

(c.) Internships, collaborative programs, and other field experiences with industry groups are strongly recommended whenever possible.

(d.) Participation in multidisciplinary team projects. (NASAD, 2008).

These essential competencies could serve the field as a catalyst for articulating the context or professional practice that define how the core body of knowledge is applied. This has a direct influence on the pedagogy and content in the PCK model of understanding industrial design, learning, and instruction. The essential core competencies, the essential opportunities to learn, and the experiences position the field of industrial design well ahead of many other technical fields in building a PCK model for learning and instruction.

Connecting Research and Defining Critical Content to Inform PCK

Robert Croston from Drexel University conducted a survey in 1997-1998 on the growth of the industrial design profession and what practicing designers expected in an industrial design curriculum. Employers of industrial designers rated subject area categories as “very important,” “needed,” or “unimportant.” The categories that were selected for the research may lend themselves to the creation of a taxonomy for PCK research in industrial design. Movement toward a taxonomy of knowledge within a field has often been elusive in technical fields of study. Examining what the core content is through research and polling of experts adds external validity to the content component of a PCK model. Croston’s (1998) categories that resulted from his research are listed in the following paragraph, and they parallel many of the accreditation areas. The critical content expressed by practicing professionals in the industrial design field include the following:

> Creative problem solving, 2-D concept sketching, verbal and written communication, materials and manufacturing process, computer-aided industrial design, multi-disciplinary interaction, concept model making, internship or co-op experience, design theory, mathematics and science, graphic design, engineering technologies, cognitive and consumer psychology, research and documentation, marketing and business practice, history of art and design, and arts and humanities.

Although the information about what practicing professionals viewed as important in these categories is interesting and speaks to PCK, the more relevant information for this discussion is the categories that were selected. Croston’s (1998) own conclusions stress the importance of teaching students through experimenting, model making, prototyping, and testing. These allow design students to understand the tangible nature of the products they design for people to use, and they address the concept of ID context and its relevance to PCK (Croston, 1998).

Wen-Deh Yeh from the University of Wisconsin – Madison (1999), conducted another informative piece of survey research searching for strengths and weaknesses in industrial design curriculums. Yeh identified seven critical competence categories made up of 69 specific competencies for industrial design graduates. Yeh surveyed industrial design educators, graduates, and employers of industrial designers regarding the importance of the individual competencies. The top five competencies reported for industrial designers were: creativity, knowledge of three-dimensional form, ability in problem solving, ability in visualizing design, and critical thinking. Specifically, Yeh’s study concluded that the central competencies of industrial designers should include the following:

- Problem-solving abilities
- Creative thinking and conceptualization
- Communication skills, visual, oral, and written
- Knowledge of human factors
- Knowledge and hand-on experience of manufacturing technology
- Form-developing skills
- Model-making skills
- Technical-drafting ability

In addition, the ability to use computer/technology to aid in the design processes and the knowledge of business practices should be integrated into industrial design education. Finally, Yeh recommended that being a continual learner is critical to an industrial designer who wants to keep himself/herself up-to-date. In light of PCK and the role content taxonomies play in defining teacher content knowledge, these findings reflect some of the knowledge, skills, and dispositions required of industrial designers.

The organization of domains of appropriate industrial design content, principles, and classroom practice within a taxonomy or hierarchy of essential content knowledge can help industrial design educators define what students both *need to know* and *be able to do* to become practicing professionals in the field. A taxonomy of hierarchical domains in the study of industrial design as opposed to the practice of design, could serve as a catalyst in helping design educators negotiate the inherent overlap between general design content knowledge, professional practice and design application context, and pedagogical knowledge. The development of an explicit teaching and learning taxonomy for the study of industrial design would alleviate the diffusion of a curriculum that claims to teach design while providing clear guidance for curriculum development. A well-understood taxonomy would also facilitate meaningful communication and cooperation among industrial design educators (Wiley, 2001). Conversation and efforts could turn to more significant work on *how to teach* rather than expend resources on *what to teach*. A well-designed taxonomy can guide the design education community and would set the stage for pedagogically powerful and yet adaptive ways that teachers could respond to varying student ability and background ; such a tool could lead to powerful teaching.

Challenges to Developing Industrial Design Educators

There are several professional complexities that interact to challenge the conceptualization of PCK for design education. Of significant challenge is the transitional phase that prevents industrial design practicing professionals from becoming industrial design educators. These professional "border crossings" between professional practice and education are not easily facilitated. Perhaps the foremost issue here is the discrepancy between compensation for successful industrial design practitioners and the design educator. Based on a salary survey conducted by a popular design website, http://www.Coroflot.com in 2007, the average salary of U.S. industrial design educators was $51,833 (an average high salary was $74,500). Professional practitioners' average salary was $79,198 (an average high salary was $175,000). Considering the significant salary gap and the additional years spent to earn the required Master's Degree to teach at the college or university level, industrial design educator salaries are even lower in terms of real earnings compared to the practicing industrial design professional. The 2000 compensation study conducted by the Industrial Designers Society of America reported sharp salary increases at all experience levels of practicing industrial designers; however, the salaries of educators with equal years of experience appeared unchanged and substantially lower than the salaries of professionals. Although this case can be made for many technical fields, smaller fields of study (like industrial design education) perhaps are affected more than larger fields.

Another key element here is the broad range of essential competencies knowledge that is required to teach industrial design effectively. A significant question remains: what level of knowledge across each of these interacting subjects does a teacher need master to effectively achieve a level of PCK in order to teach industrial design in an integrated manner? This issue represents the tension raised by Shulman (1986, 1987) on how teachers and practicing professional arrange, use, and access (or think about) knowledge within a field differently. Professionals in industrial design are constantly changing, moving, growing, and learning; they must remain current to stay competitive in an evolving market. To these professionals, nothing is more excruciating than the prospect of becoming stagnant. As a result, they may change jobs more frequently. In contrast, it appears that the "senior faculty members" or industrial design educators that have remained with a single university for an entire career make fewer job changes and repeatedly teach fundamental or core content; they have few opportunities to innovate through leading-edge contemporary design problems. Novak (2003) went as far as to assert that, many of these faculty appear to be somewhat inept in their design abilities, which may suggest that they have somehow found a place to hide.

Another issue in the quality of teaching in industrial design is the lack of training in instructional techniques and pedagogical methods for most design educators. Even if the best-facilitated border crossing could be made by bringing a practicing professional into the ranks of industrial design educator, the pedagogical component of the PCK model of instruction would be deficient. Practicing professionals can use their own instincts for teaching coupled with the teaching models that they encountered as they received their own design education. An educator who graduated from a small program would have a particularly limited frame of reference for appropriate pedagogy. This issue could perhaps be addressed by the professional organizations, like the Industrial Designers Society of America (IDSA), that offer workshops for design educators at annual conferences to increase their pedagogical knowledge. Prospective design educators also could consult the resources available to learn pedagogical techniques in technical fields (e.g., the classic, *Instructors and their Jobs* by Miller and Miller (2008). The benefit of looking at the challenges of industrial design education through the PCK concept is to allow the creation of an organizational framework for design education. This should allow an investigation into what knowledge and skills are consistently taught in the essential categories discussed in the prior taxonomy section, and the pedagogical techniques typically utilized. This research in design education should provide a means to improve overall design instruction.

Implications for Industrial Design Programs and Teaching

Why do offer PCK as an essential part of thinking about industrial design education? PCK can help educators to move on to consider the problems they face by the bifurcation of content and pedagogy implicit in standards and explicit in university practices. And finally educators can begin to examine the assumptions of industrial design, the industrial design education community, and the roles that PCK plays in this community. The general PCK interrelationships and the potential creation of a taxonomy of PCK for industrial design attributes can provide a relatively comprehensive categorization scheme for future studies of PCK development in design education (Koehler & Mishra, 2008). An interest in PCK as an epistemological perspective and as a knowledge base for design educators has produced a need for a conceptual framework upon which future PCK studies can be based. The need for taxonomies and frameworks suggested in this article provide some insight into where additional thought is necessary in industrial design education as members of the field grapple with the infusion of an ever-changing technological evolution. First, the general taxonomy of PCK will allow researchers and industrial design education programs to more accurately identify and address distinctions among knowledge bases of various industrial design disciplines, technological subjects, and topics regarding professional practice. Thus, it can provide a classification scheme for implementing unique instructional methods in the industrial design education classroom. Second, the taxonomy of PCK attributes can help researchers who study knowledge development in industrial design teachers to identify and characterize different attributes of industrial design teaching; these include content domain knowledge, pedagogy, and context to form a rich and flexible knowledge base for industrial design educators. In addition, these authors recognize the relative importance that researchers and educators have given to the different components of PCK. The need for organizational frameworks and taxonomies in industrial design education provides an opportunity to organize and integrate research efforts centered on PCK and its application in design education.

The use of taxonomies and frameworks as a foundation for future research also can provide a model for industrial design educator preparation. For example, conference and workshop programs could focus on developing topic-specific PCK for prospective design educators. Many potential industrial design educators know their content well, but they may not have learned how to transform or translate that knowledge into meaningful instruction that students can access.

What is necessary is the effective use of exemplary models of design education within topics that can later be transferred to another topic or domain. They can then apply these strategies to other topics and domains based upon their content backgrounds (Darling-Hammond, 1991).

Directly or indirectly, industrial design education programs could benefit from further PCK research. One obvious area is to identify and classify the various types of PCK employed in the industrial design classroom that appropriately infuse content knowledge and professional practice context into instruction. The importance of sponsored projects and input from current professionals outside of the faculty are also concepts that should be explored. It is our hope that the development of taxonomies will provide a foundation for future research and further discussion concerning the preparation of highly qualified industrial design educators. It is vital that all educators, develop an understanding about how to teach integrated domains in a manner that reflects the knowledge of today's industrial design content, the benefits of professional experience, and knowledge of pedagogical methods.

Dr. Kenneth R. Phillips is the Department Chair for the Industrial Design Department at Metropolitan State College of Denver, Colorado.

Dr. Michael A. De Miranda is a professor of Engineering Education in the Department of Electrical and Computer Engineering at Colorado State University, Fort Collins. He is a member of the Alpha Phi chapter of Epsilon Pi Tau.

Mr. "Ted" Jinseup Shin is an Assistant Professor in the Department of Industrial Design at Metropolitan State College of Denver, Colorado.

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