

# **A New Direction for Engineering Education Research: Unique Phenomenographic Results that Impact Big Picture Understandings**

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***Abstract:** As the pace of engineering keeps increasing, new innovations foci in engineering education research are needed. This paper presents one such innovation, away from looking at the skills engineers are to develop to focus on their embodied understanding of practice around aspects of professional practice. It does so through the use of a qualitative research approach known as phenomenography. The results of three a research projects guided by phenomenography are discussed and provide a unique lens for understanding aspects of the world that influence the practice of engineering, namely those of design across disciplines, sustainable design and cross-disciplinary practice. This paper summarizes the results from these three phenomenographic studies, emphasizing the implications these results reveal about the direction engineering education needs to head.*

## **Why do we need a new direction?**

Engineering education's main objective is to produce engineering graduates that can engage in practice as competent professionals. Traditionally this has involved defining specific attributes, including knowledge, skills, attitudes and values that are to be attained (Dall'Alba and Sandberg 1996). Education is seen as the cumulative acquisition of these attributes, also known as skills development (Dreyfus 2002). This is a reductionist approach that separates content, in the form of knowledge, skills and values, from professional practice. However "practitioners cannot meaningfully be separated from their activities and the situations in which they practice" (Dall'Alba and Sandberg 1996, p413). Content and practice cannot be separated and taught independently and still produce the level of ability that is aimed for (Walther and Radcliffe 2006). Viewing learning as filling up with knowledge fails to address the way in which the learning content is experienced by the learners, identified as critical to learning (Marton, Hounsell et al. 1984; Dall'Alba 1993; Dall'Alba and Sandberg 1996; Ramsden 2003). An alternative view to professional development is based on the existence of different ways of experiencing practice, such that "The knowledge and skills that make up professional practice are organized within an understanding of that practice" (Dall'Alba 2004, p680). The new direction that is argued in this paper is seeing professional education as both developing experiences and an understanding of engineering practice as well as developing skills within the context of practice. "Professionals not only learn knowledge and skills, but these are renewed over time while becoming integrated into ways of being the professional in question" (Dall'Alba and Sandberg 2006, p389).

## Phenomenography in Engineering Education Research

Phenomenography offers a way of investigating different ways of experiencing and understanding aspects of practice (Mann, Radcliffe et al. 2007). In engineering education research, it offers a way of understanding the ways different engineering phenomena have been experienced by practitioners thus echoing the reality of engineering practice, rather than abstract theory of what practice could or should be. The results of phenomenographic studies in engineering education are differing embodied understandings of practice around specific phenomena, and can contribute to course and program renewal and redevelopment. Further and arguably more important, they offer a different way of reframing the education of engineers as a whole, switching from students obtaining content knowledge to developing an embedded understanding of practice. The results themselves can also be understood to be stages in understanding, from less comprehensive to more comprehensive understandings. This paper presents the results of three phenomenographic studies of phenomena core to engineering practice in the 21<sup>st</sup> century, sustainable design, design across disciplines and cross-disciplinary practice. For a more complete description of the phenomenographic process see Mann, Radcliffe et al.(2007).

### Phenomenography: Sustainable Design

Sustainable design is an essential, ‘flat world’ professional skill for engineers to possess in the 21<sup>st</sup> century to respond to the challenges the present and the future hold (McDonough and Braungart 2002; Friedman 2005; Pink 2005). Our current understandings thought of what sustainable design means in practice are fragmented at best. There is no commonly agreed to understanding if what it is in the practice, as opposed to theory, as like many aspects of professional practice it is experienced in many differing ways. This research focused on these variations to help create a larger view of what sustainable design is in practice. Twenty-two sustainable design practitioners were interviewed, their transcripts de-identified and analysed using phenomenography. A set of five categories of description of different ways that sustainable design has been experienced were developed and can be seen in Table 1.

**Table 1: Categories of Description of Sustainable Design**

Category (Sustainable Design is...)	Category Description
Solution Focused	
1. Solution Finding	Sustainable design is finding a solution, either a product or process(es), to satisfy a client’s declared requirements while decreasing the associated environmental, social and economic impacts.
Problem Focused	
2. Reductionist Problem Solving	Sustainable design is the process of identifying and solving a client’s problem by taking a reductionist approach to making decisions that each decrease the associated environmental, social and economic impact.
3. Holistic Problem Solving	Sustainable design is the process of identifying and solving a client’s problem holistically on a systems level, to increase the environmental, social and economic value of the solution.
Social Network Focused	
4. Social Network Problem Solving	Sustainable design is the process of identifying and solving a client’s problem as part of a network of wider problems facing society to increase the environmental, social and economic value of the solution to both the client and society.
5. A Way of Life	Sustainable design is a way of life where all design problems, professional and personal, are solved to increase the environmental, social and economic value of the outcome to both the individual and society.

These categories represent a different way of developing an understanding of sustainable design to students. They offer context and a way of framing problems and projects where students can develop specific skills within a broader understanding of the practice of sustainable design.

## Phenomenography: Design across Disciplines

Design has been described in both broad and specific ways in the literature. It has been called an intellectual distinguishing factor of modern humans and a signature of human intelligence (Mellars, 1989; White, 1989; Wynn, 1981). Engineers are often associated with design and describe design as central to their profession ("Engineering", 2007; National Society for Practicing Engineers, 2007). This phenomenographic study explored the ways that design has been experienced by professionals both within and outside of engineering fields to better understand what it means to design and be a designer. Transcripts from semi-structured interviews with professional designers about concrete design experiences, and reflections and meanings associated with those experiences, comprised the data that were analysed through a phenomenographic lens. The results of this study included six qualitatively different ways that design has been experienced. Represented in a hierarchical form, from less comprehensive to more comprehensive, these categories of description included: Design is 1) evidence-based decision-making, 2) organized translation, 3) personal synthesis, 4) intentional progression, 5) directed creative exploration, and 6) freedom. Table 2 presents a brief description of each of these categories.

**Table 2: Categories of Description of Design across Disciplines**

Category (Design is...)	Category Description
1. Decision-making	Design is finding and creating alternatives, then choosing among them to make evidence-based decisions that lead to determining the best solution for a specific problem.
2. Translation	Design is organized translation from an idea to a plan, product, or process that works in a given situation.
3. Synthesis	Design is personal synthesis of aspects of previous experiences, similar tasks, technical knowledge, and/or others' contributions to achieve a goal.
4. Progression	Design is dynamic intentional progression toward something that can be developed and built upon in the future within a context larger than the immediate task.
5. Exploration	Design is directed creative exploration to develop an outcome with value for others, guided and adapted by discoveries made during exploration.
6. Freedom	Design is freedom to create any of an endless number of possible outcomes that have never existed with meaning for others and/or oneself within flexible and fluid boundaries.

Implications for design education are grounded in the idea of awareness. Design courses have the opportunity to help students develop well- rounded ideas about design. Students may enter the university with a variety of perspectives on what it means to experience design, but the experiences they have in a course influence their thinking. The educational system of a future professional designer can facilitate a more comprehensive view of design or teach design in a way that pushes students toward one less comprehensive way of thinking. The way design educators view design will impact that way that they talk about it and teach it to their students. While design educators may not have an extensive amount of design experience, a high level of awareness of what it has meant for design professionals to experience design can support educators in facilitating their students' development of ideas about design.

The results of this study increase an understanding of what it means to develop design skills. These include the opportunity to reflect and develop one's own meaning of design as well as an awareness of others' meanings and how those could be utilized. Expertise includes knowing what lens on design to utilize in a given context, and courses in design can be structured to facilitate students in developing their own lenses on design as well as understanding that different lenses may be applicable in different design situations.

The spread of disciplines among the categories of description has implications for education in terms of both common ground and variation of ideas. The evidence that design has been viewed similarly in a variety of fields supports the idea that disciplines can share educational development tools in design

skills. Additionally, this link across disciplines can be used in educational contexts to facilitate students' development of design skills. The ways that students experience design in one context can be a place for reflective practice when thinking about a different design context. For example, if an undergraduate is taking courses in dance choreography, this can have an important, and positive, influence on how that student comes to understand design in an engineering context, provided that the opportunity to reflect and connect these two experiences is facilitated. An education goal is to help students bring together their various experiences to build a more comprehensive understanding and to combat what students might imagine as a narrow disciplinary view of design.

The evidence that even within a discipline everyone does not have the same way of experiencing design translates to a necessity that design educators maintain an awareness of this as they develop and implement their courses. It leads to the conclusion that all students in a discipline will not have the same idea of what it means to design, and both the variety of professional meanings for design and the variety of student meanings for design should play a role in the design and implementation of a design course.

## **Phenomenography: Cross-Disciplinary Practice**

Just by reading the newspaper or talking with a colleague it is easy to see that many complex problems facing society today require cross-disciplinary approaches that integrate diverse perspectives into a collective whole. Many would argue that it is through cross-disciplinary practice that we come to understand new ways of thinking and innovating. Cross-disciplinary practice is particularly relevant for engineering in that engineering involves dealing with complex problems that require bridging disciplinary perspectives, working across technical and non-technical considerations (e.g., social, economic, cultural), flexibly adapting to new situations, and managing trade-offs where solutions are judged by interdisciplinary criteria (Bordogna, 1993; Bransford, 2007; Jonassen et al, 2006; NAE, 2004). While there is considerable discussion about and strong support for cross-disciplinary practice (CFIR, 2005), there is little research on the ways people experience cross-disciplinary practice and develop an awareness of cross-disciplinary ways of thinking, being, and acting (Adams, Mann, Daly, Forin & Jordan, 2008).

This study focuses on understanding critical differences and similarities in the ways people experience cross-disciplinary practice in *engineering contexts*. Here, "cross-disciplinary" broadly refers to concepts used to characterize practices associated with thinking and working across different perspectives such as multidisciplinary, interdisciplinary, and transdisciplinary. Twenty-two (22) people participated in this study. To explore critical variations in cross-disciplinary practice, we recruited people who differed in their context of work (academia, private industry, and community service), level of cross-disciplinary experience, gender, and diversity in the types of perspectives encountered in their work. Each was interviewed for approximately thirty minutes where they were asked to describe a critical experience around cross-disciplinary practice.

Unlike the other two studies in this paper, this study is in the final analysis phase of defining categories and relationships among categories. Preliminary findings are presented below in Table 3 where the hierarchical relationship progresses from category 1 to category 4. Across categories we are observing variations in communication practices and the process of developing common ground, identities as cross-disciplinary practitioners, the ways in which human aspects are portrayed in complex technological and social problems, and the ways in which people critical reflect on both their disciplinary training and the nature of cross-disciplinary practice.

While it is early to identify theoretical and practical implications, some interesting issues are emerging. First, the categories of description emphasize cross-disciplinary practice as working together. This leads to questions about how cross-disciplinary practice compares to collaborative work. One response is that this study illuminates an awareness that people have different training, perspectives, and lived experiences that impacts the way they think, what they value, and how they collaborate and communicate. Another response is that cross-disciplinary work is rarely done alone and is therefore inherently collaborative. It may also be that most research on collaborative work focuses on processes such as the behaviours and actions of those engaged; in contrast, a

phenomenography lens focuses on how collaborative work is experienced. As such, this study might provide a new window into theories of collaborative work.

**Table 3: Categories of Description of Cross-Disciplinary Practice in Engineering Contexts**

Category	Category Description
1. Working together	Cross-disciplinary practice is working together with people who have different training to effectively find a better solution. This involves (1) asking questions and listening for understanding, (2) being comfortable with asking for information that might seem obvious or trivial, (3) knowing what you contribute and what others can contribute, (4) recognizing differences in how people think and communicate, and (5) valuing that everyone has something to contribute.
2. Intentional learning	Cross-disciplinary practice is intentional learning so that everyone gains (me, my team, and my customer). This involves (1) learning <i>through</i> experience and failure, (2) learning <i>how</i> to negotiate meanings across perspectives and formulate or investigate problems through multiple lenses, (3) educating each other to collectively enable a systems perspective, and (4) creating opportunities to learn new perspectives or ways of knowing.
3. Strategic leadership	Cross-disciplinary practice is strategic leadership to enable cross-disciplinary work and facilitate a better outcome. This involves being the “interface”, “connector”, or “communication specialist” that enables (1) making conceptual connections, (2) a systems-oriented starting point, (3) cycles of iterative and innovative activity, (4) building allegiances to a shared goal or plan, and (5) drawing from appropriate strategies to get the job done well.
4. Questioning practice	Cross-disciplinary practice is questioning practice to span systems and produce an outcome greater than the sum of its parts. This involves (1) advocating and empowering different and often low visibility perspectives by taking a high level view of the situation that takes into account the broader context, (2) building relationships that engage individuals and cultures, particularly those impacted by potential solutions, (3) attuning to the human aspect of real problems, (4) embracing cross-disciplinarity as a part of everyday practice, (5) critically reflecting on the nature of authority, attributes of good solutions, and the boundaries people create (such as disciplinary boundaries), and (7) valuing conflict across perspectives as a way to bring important issues to the foreground.

From a practical standpoint, a view that cross-disciplinary practice shares qualities with collaborative work suggests that extensive disciplinary training may not be necessary for participating and learning through cross-disciplinary practice. In other words, this study begins to suggest that it would be not only feasible but also beneficial to engage students early and often in collaborative work that involves interactions with people who have different training or points of view. This challenges views on waiting until students specialize in an area of disciplinary expertise (i.e., through a baccalaureate degree) before engaging them in cross-disciplinary experiences. It also challenges views on what students learn through collaborative work by opening a door for more proactive learning on cross-disciplinary ways of thinking, being, and acting.

## New Directions for Engineering Education Research

This paper presents phenomenography as a qualitative research approach able to develop new understandings and insights of aspects of professional practice. It can provide an understanding of the critical variations between the ways a phenomenon has been experienced, rather than aggregating concepts in a way that loses important learning differences. It also can provide a further way of understanding the translation from the university to practice, as the results are the ways that the engineering practice has been experienced. Further, phenomenography also offers a way to better understand the practice of engineering through empirical research on actual practice, rather than based on what practice could or should be in theory. Finally it provides a systems view that illustrates the relationship between deep and surface understanding of a phenomenon.

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