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By Sili Law

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For the degree of Master of Science

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THE PRACTICE OF ENGINEERING TEACHING

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ABSTRACT

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This thesis focuses on several aspects of engineering teaching in the household by parents with engineering backgrounds. It seeks to explain why certain concepts are taught by the parents and why certain strategies are used to convey the concepts. First, the linkage between the ways parents use to teach their children and certain engineering concepts taught by the parents is a unique practice in the engineering field that needs to be carefully examined. Second, engineering concepts that are taught by the parents and strategies used to teach such concepts have close relationships to both the constraint of certain structures as well as individuals' interactions. Third, engineering concepts have different connotations to practitioners depending on their various backgrounds. Practice theory shows strength in understanding such aspects of engineering teaching. New approaches are added to the role model of practice theory to solve the macro-micro linkage problem and examine how individuals take on practices from the multifaceted states in which they find themselves.

CHAPTER I: INTRODUCTION

Motivation

The thesis focuses on several aspects of engineering teaching in the household by parents with engineering backgrounds. It seeks to explain why certain concepts are taught by the parents and why certain strategies are used to convey the concepts. Further, the thesis tries to explore what anthropology could contribute to engineering teaching from a unique perspective, and how engineering teaching as a cultural practice provides anthropology new topics in the 21^{st} century.

Teaching engineering in K-12 classrooms has been a relatively new practice. However, before engineering was introduced to K-12 classrooms, it had already been taught (either intentionally or incidentally) outside of classrooms by parents, particularly those who have engineering backgrounds. Engineering can be taught both by teachers in classrooms and parents during their daily interactions with children, and as two facets of engineering teaching, they sometimes work hand-in-hand. For example, with older children in this study, parents teach engineering in the form of assistance. They help their children with school projects such as "science fair projects" and help explain problems that appear in children's homework. Schools, in turn, sometimes invite engineer parents to classrooms to demonstrate engineering or science-related topics and try to stay in contact with industries through engineer parents' networks. On the other hand, teaching engineering by parents is sometimes dissociated from teaching engineering by school instructors in classrooms. This is because parents have an intimate relationship with their children, and this close bond opens up avenues of teaching that are unlikely to take place with people who do not possess such a relationship. For example, in this study, some parents use bedtime stories to help their children discover the science behind daily phenomena, such as "fog on the window" and "lightning in the sky". Therefore, studying how parents teach engineering is just as important as studying how engineering is taught in K-12 classrooms.

I started this study with an interest in what and how K-12 engineering is taught by engineer parents outside of classrooms. The interest stemmed from the underrepresentation of women and non-Caucasian engineers that American engineering education has been experiencing. As shown by the data from the *2009 Profiles of Engineering and Engineering Technology Colleges* (Gibbons 2009:2), the total enrollment of engineering in all degrees (Bachelor's, Master's, and doctoral degrees) showed a robust growth in 2009, with the Master's and doctoral enrollment reaching an all-time high (2009:1). However, compared with Caucasian representation which has always remained proportionally larger (over 50%), Asian (12.4%), African-American (4.4%), and Hispanic (6.6%) representations remained unchanged at all degree levels, receiving a much smaller share of degrees. On the other hand, although at both the Master's and the doctoral level the number of engineering degrees awarded to women has been increasing, it has never outreached 23 percent.

Despite gender and race inequalities that are used to explain such a situation, this underrepresentation of women and non-Caucasian engineers might also suggest their lack of an engineering role model when they grew up. As Susan Mannon and Paul Schreuders (2007:1) discovered in their research, "half of the men and women engineering students had at least one engineer in their family with women significantly more likely to have an engineer parent", and "women with an engineer in their family were significantly more likely to decide to study engineering before college". Mannon and Schreuders also pointed out that parents, by virtue of their own occupational backgrounds, socialize their children to take on particular educational aspirations and occupational interests. This study linked the problem of the underrepresentation of women engineers to the phenomenon of occupational inheritance, and thus provided a new angle to tackle the problem. For example, children from a non-engineering family might benefit by being exposed to more engineering-related knowledge, interests, and aspirations at an earlier age if their parents are introduced to engineering concepts and skills as well as the methods to teach them. With such an exposure, children are likely to have more knowledge about engineering before they start making their career choices. Further, such an exposure will also likely prevent students from opting out of engineering due to an unfamiliarity to it.

The initial intention of this study was to find out 1) Are engineers really teaching their children engineering? 2) If so, what and how do they teach their children, and eventually, 3) can their educational interactions be introduced to non-engineer parents and thus pave the way towards engineering for their children?

Methods and Reflexivity

Following the classic ethnographical method of participant observation, together with 24 semi-structured interviews, and tweaked with a good deal of reflexivity, this study explores various notions of engineering knowledge. My aim was to find out what is perceived as engineering knowledge by engineers themselves and how the knowledge is reproduced through practice. My field has been the two years of working experience as a research assistant in the School of Engineering Education (ENE). In this time, I have been constantly traveling from the dark and nostalgic-looking anthropology building to the modern-looking engineering building with large glass windows, from a group of "cultural people" to a group of "problem solvers". Every step I took was a foreign encounter, and every interpretation I had of my foreign encounters was my field. My field was, however, more than the experiences and their interpretations. It was also the invaluable friendships I established with the engineers of various fields, whether they were my office mates in ENE, my project supervisor for and with whom I worked, the other professors in the ENE department, the acquaintances with whom I intentionally sought to socialize for the sake of my project (and who became good friends of mine in the end), and the new network I have established through this study.

In order to coordinate my research purpose with my supervisor's (which is to investigate the practices that parents with engineering backgrounds employ to help their children learn about engineering), I interviewed 24 parents who were self-identified as parents of children ages 2-18 who "help their children learn about engineering" (Zhang and Cardella, presented in 2010). Parents with diverse backgrounds were self-selected and contacted us, willing to be interviewed. These parents came from different engineering fields, from academia or industry (or both), and had children of various ages and sexes. Each parent participated in a semi-structured interview that lasted approximately 60 minutes. I began by asking the parents about their children, their children's schools, and their own academic backgrounds. I then asked them to describe in detail how they helped their children learn about engineering; follow-up questions were also asked based on their responses. The flyer used to recruit participants for the interview was targeted towards parents with engineering backgrounds who also taught their children engineering (see the facsimile of the flyer in Appendix 1).

The variables of this study are the diverse backgrounds of the parents, their children's ages and genders. Of the 24 participating parents, 12 were mothers and 12 were fathers. Fourteen of the 24 parents were faculty members, two were Ph.D. students, and eight were in industry. The two parents who were Ph.D. students have also had nine and 30 years of experience in industry prior to entering their Ph.D. programs. The ethnic backgrounds of the parents were quite diverse, including 16 Caucasian-Americans, two Asian-Americans, one African-American, and three foreign nationals (two Chinese, one Hispanic). The remaining two parents' ethnicities were unrecorded. The parents' work and educational backgrounds touched on 20 specific engineering fields, including civil engineering, biomedical engineering, aerospace engineering, electrical engineering, and industrial engineering. Most parents experienced multiple engineering fields before making their career choice. For example, Ben received his Bachelor's degree in electrical engineering, received his Master's and doctoral degrees in science and technology, and is now working in the field of engineering education (see Table 1.1).

Out of the parents' 50 children, 26 were girls and 24 were boys. The children's ages ranged from 17 months to 29 years, and 39 out of the 50 children were within our desired age range of 2-18 years. The parents' teaching experiences were age specific. For example, Laura's boy is 10 years old, and she teaches him how to use a blender by giving him the instructions to read. Jean, on the other hand, whose daughter is only two-and-half years old, teaches her daughter how to take toys apart and how to put them back together. It is also worth mentioning that when parents talked about their older children (for example, teenagers or even adults), they were usually talking about their old teaching experiences when their children were much younger.

The interview questions covered the parents' backgrounds, their interactions with their children (for example, the content they teach their children, teaching strategies, and the children's reactions), their parenting philosophy, and their own understandings of engineering (see Appendix 2). Although our recruiting flyer specifically asked for parents with engineering backgrounds who also taught their children engineering, and the parents were consequently self-selected, almost every parent claimed that they didn't teach their children anything specific, including engineering. As I tried to avoid imposing my questions onto these parents, probing was very difficult. Eventually, I had to loosen up the parents by asking them about their children's interests and personalities. Most of them would tell me that their children enjoyed exploring the sciences, fixing things, painting, and such. Then I asked them when and how they started to notice their children's interests (only engineering-related), and the parents usually started talking about their experience of either introducing or reinforcing engineering interests for their children. Questions regarding parenting philosophy and parents' own understandings of engineering also helped bring out some engineering-related teaching experiences. When asked to sum up their interactions with their children at the end of the interviews, parents did admit that they were teaching their children something related to engineering. However, they also clarified that they taught their children engineering not because they expected their children to become engineers in the future (though they wouldn't object to such a career choice), but because engineering is a part of who they are and what they are most familiar with – "it is just natural", one parent said.

Regardless of the participants' linguistic backgrounds, all interviews were conducted in English so that my supervisor and I could both have easy access to them. Limited by the language, some Chinese parents gave me more information in Chinese after the formal interview was done. The quoted responses used for analysis in the later chapters were recorded, transcribed, and kept verbatim. To keep the participants' information confidential, all names used in the thesis are pseudonyms (also, see Appendix 2).

Structure of Thesis

This study focuses on several aspects of engineering teaching and investigates what is taught about engineering and how it is taught. First, the linkage between the ways parents teach their children and certain engineering concepts taught by the parents is a unique practice in the engineering field that needs to be carefully examined. Second, as part of the transmission of knowledge, engineering concepts that are taught by the parents and the ways in which the concepts are taught have close relationships to the constraints of both certain structures and individuals' interactions. Third, engineering concepts have different connotations to different practitioners depending on their various backgrounds. The purpose of this study is to use practice theory to explain such aspects as well as to provide new approaches of practice theory that are unexplored.

Chapter II briefly introduces the commonly shared orientation of practice theory and how it is useful in this study. I explore two approaches as a complement to the role model of practice theory. The first approach is to bridge the gap between the macro and micro levels of practice theory. By incorporating the macro-social phenomena, which are bound to large-scale social categories, and micro-social phenomena, which emphasize individual psychology and interactions within small events, one could achieve a more complete picture of the interactions between mutually influencial individuals and shared practices in relation to structures. In order to do so, social psychological theories are also used. The second approach deals with the fact that individuals interact with multiple groups of people. Given such conditions, looking at group practice alone would overlook how individuals take on practices from more than one group. To solve this problem, my approach looks at how, through practices, individuals configure multiple structures in which they live.

Chapter III discusses Polanyi's notion of tacit knowledge and its contribution to practice theory. Relationships between tacit knowledge and explicit knowledge were examined and applied to the practice of engineering teaching. Problems of Polanyi's notion of tacit knowledge such as the contingency of tacitness and its embeddedness in social contexts are also included to navigate the application of tacit knowledge to the practice of engineering teaching in a new direction.

Chapter IV applies practice theory to analyze specific interviewee cases. First, the role model of practice theory is used to explain where different perceptions of engineering as well as strategies used to teach engineering originated; how they are maintained, reproduced, and changed; and why they are changed. Then, as part of the knowledge transmission, the process of engineering teaching is examined both from a macro and micro perspective.

In Chapter V, different connotations of problem-solving, an engineering concept, are carefully examined using practice theory from a more individual perspective. Theories of globalization such as concepts of "figured world" and "site" are introduced to help understand the individuals' configuration of various cultures and its relationship to the various connotations of problem-solving.

In summary, practice theory shows strength in understanding engineering teaching in terms of what is taught and how it is taught. In turn, engineering teaching as a cultural practice opens up new topics for practice theory. This study allows us to see how anthropology can contribute to engineering education and how engineering education as a cultural practice in turn brings new insights to anthropological and other social theories.

CHAPTER II: REVISIT PRACTICE THEORY

The Role Model

Recent conceptions of culture as practice, or practice theory, have been useful for this study in order to understand engineering in terms of where perceptions of engineering and ways of teaching engineering originate as well as why and how these perceptions and ways of teaching change or are maintained over time. Driven by different questions, scholars of different persuasions have established many diverse approaches to study practice. While I do not attempt to compare or contrast these diverse approaches, I wish to mention the commonly shared orientation of practice theory between these approaches that I have applied to this study. Starting from the 1980s, the dominant view of culture as actions enacting or executing rules and norms began shifting to the view of culture as practices that are inscribed in the ways that individuals use their bodies and are constrained by the "structure", "habitus", or "system" (see Bourdieu 1980; Giddens 1979; Ortner 2006; Swidler 2001). Practice theory unfolds the circular relationship between practice and system – how a system is originated, reproduced, and changed through practice which in turn is constrained within such a system.

In this study, although different engineering concepts were introduced to children by their parents, the concepts themselves, including problem-solving, designing, and following instructions, are not unique in being taught by engineer parents. For example, the skill of problem-solving as content is not only taught by engineer parents; a math teacher could teach his/her child problem-solving, too. Additionally, the strategies used by the parents to teach certain concepts, such as building things together and taking children to museums, are not exclusive to engineer parents. A carpenter might teach his/her child how to build a deck with or without any further intentions. However, such a practice might be used by an engineer parent as a strategy for it inevitably conveys certain engineering ways of thinking, either consciously or subliminally. For example, in his interview, Matt described his experience of building a deck with his daughter. He started by having a discussion with his daughter about the function of the deck, the benefits of the deck, and where the deck should be built. Then, he talked to her about how the deck is designed (for example, what materials should be used and why), how the deck is expected to look, and how the deck will match the style of the entire house. When he finally started to build the deck, he taught her how to use the tool kits, how to put things together, and how the deck operates (i.e., the deck's physics). To Matt, building a deck is a strategy used to teach engineering-related concepts such as physics, design, and problem-solving. Therefore, using a specific strategy to teach a specific engineering concept (or several engineering concepts) is a unique practice found among these engineer parents. To apply practice theory to this study helps unfold how this practice is constrained as well as inspect what kind of engineering ideology is reproduced through the practice.

The Macro-Micro Problem

This study also applies practice theory with approaches heretofore unexplored with practice theory. First, as Jeff Coulter (2001: 29-39) pointed out, the diverse strands of practice theory have represented an unresolved problem of the "macro-micro linkage". By "macro", Coulter refers to the "macro-social" phenomena which are bound to large-scale social categories, such as states, institutions, firms, and ethnic groups. For example, Michel Foucault (1984) focused his attention on how military disciplines were inscribed into the soldiers' "docile bodies". Sherry Ortner (2001: 401), too, has articulated her position on the macro end and has pointed out an "irony" at the core of the practice model in that "although actors' intentions are accorded central place in the model, major social change does not for the most part come about as intended consequence of action". "Micro", on the other hand, refers to psychology and interactions on the individual level in small events. For instance, in *The Presentation of Self in Everyday Life* (1959), Erving Goffman demonstrated how selves are presented differently by individuals based on various interactions and how it is that people come to an assumption that they understand each other's conversation. In addition, sociologists studying ethnomethodology and social interactions take a similar stand and believe that it is within the social interactions between people that the macro-social phenomena exist and become meaningful (See Harold Garkinfel 1970 and Herbert Blumer 1986).

As shown above, while social theorists have stated their positions on the macro-micro problem, few have attempted to incorporate the micro perspective and the macro perspective together. However, either the macro or micro approach alone applied in practice theory can result in problematic interpretations. As Coulter (2001:38) pointed out, practice theory on the macro level alone is usually constrained in explaining the linkage of "macro-social identities" and "open categorical practices". "Macro social identities" refer to the memberships in macro social categories, such as teachers, football players, and patients. The practices that are bound to these categories can be teaching, football training, and getting treatments, respectively. "Open categorical practices" refer to practices that are not bound to any specific social categories, such as laughing, eating, taking a shower. Therefore, the macro perspective alone fails to explain some seemingly conflicting relations between social categories and categorical open practices (for example, a professor caught selling drugs). In addition, practices that are usually bound to certain categories may be assumed without taking other factors into consideration, and as a consequence stereotypes emerge. For example, an Asian woman seen cooking for her husband could be understood as playing a typical role of an Asian woman who takes care of the housework. However, a micro inspection might suggest that the husband cooks most of the time and that the wife was cooking only because her husband was too busy, or because she had interest in trying a new recipe.

On the other hand, practice theory on the micro level itself is too momentary and can result in narrow understandings of human interactions and material objects that instead need to be situated in a complex matrix of shared history, attitudes, and beliefs. Ann Swidler (2001:56) pointed out that although practices vary from situation to situation, schemas enacted by a practice can transpose all situations and be read from practices themselves. She used house building by architects in different cultures as an example and pointed out that even though the styles and techniques of building houses are different, the underlying "constitutive rules" (disposition in Bourdieu's sense) are the same. What a house is, how a house is used, the idea that a house can be possessed, the human relations arising from house-building, and the vocabularies produced during the process will depend on the cultural context rather than varying from situation to situation.

Therefore, an incorporation of both the macro and micro is highly critical to practice theory, for it would provide us a more complete picture of what people do, how they do it, their motivations to do it, their emotions arising during interactions, and the structure within which people practice. In this study, I will incorporate the macro and micro social phenomena as my first step in tackling the macro-micro problem. On the macro level, I will inspect the circular relationship between practices of engineering teaching, structures, and cultures, using both sociological and anthropological theories. On the micro level, I will examine individual approaches used by parents to teach engineering concepts and skills in relation to specific situations, personal interactions, and identities taken up by the parents. In order to do so, I will bring in some social psychological theories such as processual social interactionism, ethnomethodology, and Goffman's social theories.

An Individual Approach

While the approach of incorporating macro and micro analysis provides a more complete picture of how engineering teaching is done and why it is done in certain ways, this approach, as a solution to the problem of macro-micro linkage, stays on the surface level. The consequence of such a problem is still somewhat neglected. In the contemporary world where new disciplines, social organizations, and professions emerge as more specialized yet more interdependent than ever, an individual can have multiple cultural backgrounds and cross boundaries constantly on a daily basis (for example, when kids go to school they cross the boundary of home and school).

Matt shared his cultural backgrounds with many groups of people, including middle class Americans, professors, engineers, Protestants. Given such a complex background, looking solely at group practice will overlook how individuals take on practices from more than one group. Therefore, I propose to take an individual approach here and inspect what/how different practices are taken from different groups by individuals as well as the meaning behind such a configuration. To further explain this approach, one may take a look at Swidler's (2001:56) house building example from a different angle. Suppose there is a Japanese architect who is an environmentalist, is influenced by neoclassical architecture, and is designing a house for a Chinese enterprise. How the architect designs the house has to do with: 1) whether or not the materials are environmentally friendly, 2) how to coordinate the house with neoclassical styles, 3) the implicit assumptions of Japanese houses, and 4) the requests of the Chinese enterprise (for example, the building needs to avoid bad *feng shui*). Viewed from this angle, the practice of house building is therefore a selective reproduction of multiple subcultures, sometimes conscious and other times subliminal.

By emphasizing an individual's practice within multiple subcultures, I do not intend to advocate studying individual practices rather than collective practices because neither collective practices nor individual practices alone can shine light on practice theory; rather, it is the interactions between individuals that make things meaningful. Similar to the above example of building a house, the field of engineering is filled with people from complex backgrounds and consists in many divergent and corss-cutting paths throughout its own history, resulting in many different practices and a unique manifestation of practices. Therefore, without a solution to the problem of macro-micro linkage, practice theory may overlook these individuals who have backgrounds in multiple fields of engineering in which concepts of engineering may be similar and conflicting at the same time.

For example, some earlier engineering fields (civil engineering, mechanic engineering) place greater emphasis on the practice side, and to these fields the core value of engineering is to be hands-on. In other fields that emerged relatively later (software engineering, biomedical engineering), engineers might be required to have strong theoretical backgrounds, and the core values of engineering are science and math. The engineers emphasize more on the minds-on side. However, most of the engineer parents have had experiences with multiple fields of engineering, and focusing solely on the collective practices of civil engineering or software engineering (for example) will neglect the multiple influences introduced by possessing a background in both fields of engineering. Thus, to solve this problem, one has to take into account where the differences originate, how individuals come to different understandings of what engineering is, and how the configuration of different understandings make sense to these individuals. To do so, I propose an individual approach analyzing the specific process of how individuals configure multiple ideologies through practice as the second step to solve the macro-micro problem.

To complement this approach, theories of globalization such as concepts of "figured world" and "site" (See Tsing 2005: 200-213, Appadurai 1990:7) show strength in this particular case. Understanding how individuals construct their imagined worlds during transnational experiences has greatly shed light on practice theory that looks at individuals' configuration of multiple ideologies. This particular case will be discussed further in Chapter III. Meanwhile, this individual approach used to complement practice theory has suggested a new way to look at agency. As previously discussed, the emergence of practice theory has changed the flavor of human actions from enacting social norms to the state of being shaped and constrained by asymmetric social structures (Ortner 1994). Such a shift allows a substantive amount of human agency and provides more room for discussion. While I do not attempt to discuss whether agency is resistance to "hegemony" or just simply the ability to act, the individual approach of practice theory I propose here suggests that agency, in a complex environment such as the field of engineering, is the ability to configure multiple habitus dispositions that people share with multiple groups, both consciously and habitually (See Bourdieu 1980). The result of the configuration, as Ortner has suggested, does not always coordinate with individuals' intentions and therefore is highly contingent. This will also be discussed in Chapter IV.

CHAPTER III: PRACTICE AND TACIT KNOWLEDGE

The "Bike-Riding" Metaphor

The term tacit knowledge was first mentioned by Michael Polanyi (1967) and has been fruitful in many social/cultural studies. Many new studies have been derived from interpretations of conflicts between tacit knowledge and explicit knowledge demonstrated by Polanyi (i.e., knowledge management) in which tacit knowledge is believed to be able to transform to explicit knowledge (see Nonaka and Takeuchi 1995). Following a distinguished career transformation from a scientist to a philosopher, Michael Polanyi conveyed a great passion with respect to the knowledge about knowledge. He claimed to be in debt to Gestalt psychology as well as heuristics, but his studies go far beyond them. Many of the experiments that he uses to demonstrate his ideas about knowledge are derived from the experiments done by the Gestalt psychologist as well as scientific experiments done in various fields of science. In his works, Polanyi uses "knowledge" and "knowing" interchangeably, which could not be conscious and might be attributed to the fact that he views knowledge as both an action and a process, something I will discuss in later paragraphs.

The structure of knowing, which is composed of practical knowledge and theoretical knowledge, was inspired by the structure of Gestalt – the "*wissen*" and the "*können*" – as well as Gilbert Ryle's (1949) "knowing what" and "knowing how" (Polanyi, 1967: 7). Influenced by both Gestalt structure and Gilbert Ryle's notion of knowledge, Polanyi divided knowledge into two dimensions – focal knowledge and tacit knowledge. Focal knowledge is "knowing a thing by attending to" an entity as a whole, and tacit knowledge is "knowing a thing by relying on our awareness of it for the purpose of attending to an entity to which it contributes" (1969:601-616).

To further illustrate them, Polanyi discussed some examples of motion study including riding a bike and swimming in the pool. For the biker, the focal knowledge is to know how to perform and coordinate the muscular acts while riding a bike, and the tacit knowledge is to have internalized the muscular acts on which the performance of bike riding relies. According to Polanyi, bike riders may know how to "coordinate the muscles" (1969:601) in order to ride, yet not know how each specific muscle works. In fact, if they do know how each muscle works and keep thinking about these muscular moves, they might fall from the bike.

In his 1965's essay *The Structure of Consciousness* (1969:601-616), Polanyi further elaborated this distinction by discussing focal awareness and subsidiary awareness. His example of stereoscopic viewing further explains how the two types of awareness coordinate in the process of knowing. The stereoscopic pictures Polanyi refers to are a pair of slightly different pictures taken from two points of view a few inches apart. When looking at a pair of these stereo-images, whether by parallel viewing (which requires one to relax both eyes and look beyond the image) or by cross-eyed viewing (i.e., the left eye looking at the right picture and the right looking at the left), one can perceive a different image. Viewed in either way, the objects' spatial relationships (for example, depth) in the resulting stereo-image will be revealed, and the *meaning* of the image becomes comprehensive. Hence, the two separate pictures become subsidiary to the viewing of the stereo-image – the joint focus of the pictures. The pictures serve as a clue and a tool (which Polanyi also calls a *tacit inference*): to bring out the joint meaning of the two images – the focal knowing of the stereo-image. However, if one focuses on the two pictures themselves instead of the stereo-image as a whole, one loses the meaning of the whole, and the process of logical disintegration has reduced a comprehensive entity to its relatively meaningless fragments. Therefore, the focal knowing and the subsidiary knowing are mutually exclusive in this process of knowing. It is worth mentioning that Polanyi did not explicitly try to distinguish subsidiary knowing from tacit knowing most of the time but rather used these two terms interchangeably and sometimes confusingly. When tacit knowledge is used interchangeably with subsidiary knowing, it has the same meaning that is distinct and mutually exclusive from focal knowing. However, when tacit knowledge is used alone (which seems to be the case most of the time), it usually refers to a process of integrating what is already focally known (explicit inference) to subsidiary knowing. Tacit knowledge and explicit focal knowledge are not located in two separate brains but rather grow with each other. What is focally known right now might become tacit in the future, and what is tacit will always influence how our focal knowing is achieved. Tacit knowledge as an integration of both focal knowledge (explicit knowledge) and subsidiary knowledge (implicit knowledge) is constantly changing and maybe even accumulating.

Tacit Knowledge and Practice Theory

In his earlier essay *Tacit Knowing: Its Bearing on Some Problems of Philosophy* collected in *Personal knowledge* (1962: 2-3), Polanyi has a more comprehensive discussion of tacit knowledge as a process as well as tacit knowledge's structure:

> What is subsidiarily known is tacitly known; but it seems appropriate to extend the meaning of "tacit knowing" to include the integration of subsidiary to focal knowing. The structure of tacit knowing is then the structure of this integrative process, and knowing is tacit to the extent to which it has such a structure. So if (as it will appear) all knowing ultimately relies on a tacit process of knowing, we shall say that, ultimately, all knowledge has the structure of tacit knowledge.
> Tacit knowing cannot be strictly opposed to focal knowing because the process of tacit knowing includes our knowing of the subsidiary particulars in terms of the entity to which they contribute and to which we are focally attending. But the tacit character of knowing can be reduced by switching our attention to the particulars. We replace then, to this extent, tacit knowing by explicit inference, and in this sense tacit knowing can be opposed to (focally known) explicit inferences.

There are several theses that could be derived from the statements and examples given above. Firstly, knowledge is functional in the way that tacit knowledge is a tool which we use to know whatever is in focus. The practice of our explicit knowing is deeply embedded in the tacit knowledge of which we might not be aware. Secondly, the structure of knowledge is a constant and circular process of knowledge reproduction – a process of strategic configuration of what is in focus at the moment to what was tacitly known in the past. The knowledge reproduction will eventually become tacitly known in the future and participate in the new cycle of reproduction.

Hence, tacit knowledge is never completely unconscious or opposed to focal knowledge. On the other hand, because of this structure, knowledge in whatever form is always partially tacit. Thirdly and most importantly, to take it farther and recast the role model of practice theory here, how we attend to focal knowledge is partially shaped and restrained by what composes tacit knowledge ("traditions" as called by Polanyi, cultural norms, social structures, and other focally known knowledge). What is focally learned is also practiced with caution and constantly confirmed and reinforced. Eventually, it becomes validated, taken for granted, and transmitted to other people as the *truth*. Thus, after being integrated into tacit knowledge, focal knowledge is no longer in need of substantiated, and the whole entity becomes taken for granted, or (in Bourdieu's term) *habitual*. Focal knowledge reshapes what was already tacitly known once it is integrated into it and becomes part of the new tacit knowledge.

Problems of the Tacitness

There is, however, a problem with the tacitness of the type of tacit knowledge in Polanyi's bike-riding example. As Harry Collins (2001: 108-117) pointed out, in order to ride a bike, one must first learn about the required muscular moves, and it takes some practice for new bikers to get use to the moves and focus on bike-riding as a whole. To Collins, there exist two types of learners, which he believed to be a "fact". The first type learns how to use their muscles and these learners immediately become flawless bike riders. The second type, however, takes a long time to practice and still might not become proficient bike riders. Collins believes that the quick learners of the first type will pick up other types of knowledge just as fast, and therefore this type of tacit knowledge has no tacitness but rather is just "a contingency of how we are made and how difficult certain tasks are in relationship to our brain capacity" (2001: 112). Collins made a good point that the tacitness of some tacit knowledge might be contingent, for it depends on how differently individuals' brains are wired (and maybe the various degrees of familiarity to such knowledge as well).

On the other hand, Collins also pointed out that the bike-riding metaphor only focuses on knowing how to maintain balance on the bike while ignoring different aspects of bike-riding, such as riding in traffic. When riding in traffic, what is tacit becomes much more complicated. For example, one might exchange eye contact with a car driver while passing a cross road, and how the eye contact is understood depends on the current social context. Therefore, the tacit knowledge of riding a bike in traffic requires embedding in the social context of the current situation. With these two perspectives in mind, it becomes critical that when we look at how tacit knowledge influences the way we learn, we must also investigate the social context on the macro level as well as the contingencies of the tacitness due to individual differences on the micro level.

Tacit Knowledge and Engineering Teaching

In this study, the explicit knowledge consists in the engineering concepts taught by the parents, and the tacit knowledge is more complex. Parents teach various engineering concepts based on their own perspective of what engineering is. For example, some parents believe that science and math are the key to engineering, some perceive engineering as the ability to build things, some emphasize problem-solving skills, while some disagree and believe that the ordinary maintenance of machines is engineering, too. How engineering is perceived relies on the parents' tacit understandings of engineering, their past experiences with engineering, and different engineering cultures with what they associate. Also, when looking at the tacit knowledge that the parents rely on to achieve different understandings of what engineering is, it is important to investigate the social context in which the process of understanding engineering takes place, the cultural aspects which can contribute to the understanding of engineering, and the individual differences between the parents. With this in mind, I will proceed to discuss in Chapter IV how the concepts of knowledge are realized by the parents through the practice of engineering teaching and how tacit these practices are.

CHAPTER IV: THE PRACTICE OF TEACHING ENGINEERING

Engineering Teaching on the Macro Level

There are two types of knowledge that need to be discussed in my study of engineering knowledge transmission (Zhang and Cardella, 2010). One is the explicit skills and concepts gained in a specific field through disciplinary learning, or whatever knowledge that is in *focus* in the engineering field, and the other is tacit knowledge, or the different epistemologies we believe in and practice every day to know and make sense of the world. Tacit knowledge is the tool we use to achieve the focal knowledge, be it cultural knowledge, commonsense knowledge, or agency, which together with the new knowledge in focus can reproduce a new form of tacit knowledge. As I have discussed in the previous section, explicit knowledge and tacit knowledge are not mutually exclusive. However scientific the former might be, it is always limited by the latter which we practice almost unconsciously in everyday life. However encompassing our commonsense knowledge might seem to be, our explicit knowledge gained from systematic learning in turn reconstructs our commonsense knowledge by a series of rejections, confirmations, and readjustments. Therefore, as Judith Friedman Hansen, an anthropologist interested in human learning and the processual study of learning and knowledge transmission, states, "the transmission of knowledge is subject both to conservative forces and to tendencies toward continual redefinition" (1982:26). In this case, the explicit knowledge being transmitted from parents to children is more transparent. The knowledge is everything that parents think is engineering-related – fixing a household item, building an electric circuit, practicing mathematics skills, and understanding how things work. The commonsense knowledge, however, is more complex, pervasive, and taken for granted during most of our waking hours. According to Hansen

(1982), commonsense knowledge, which she calls cultural knowledge, is a set of maxims, ideas about human nature, aesthetic preferences, values, affective patterns, and beliefs (Hansen, 1982:25). According to Kenneth Leiter (1980) and Alfred Schutz (1970), commonsense knowledge does not only include the "rules of thumbs that are vague, contradictory, and self serving", but it can be studied from three dimensions – the stock of knowledge, the natural attitude of everyday life, and the practices of commonsense reasoning (Leiter, 1980: 54). Many of these dimensions hinge upon the various assumptions people make about each other and each other's reasoning. In this study of parents' teaching experiences, I examined the process of knowledge transmission by looking at the interactions of these two types of knowledge and how parents reorganize these types of contradictory as well as mutually sustaining knowledge to selectively share it with the next generation.

Knowledge transmission reflects social structure. Social structure is viewed by Sewell as "dual", as "both the medium and the outcome of the practices which constitute social systems". Social structure also "differs in 'depth' (how pervasive, invisible, and taken-for-granted their schemas are) and 'power' (how great the resources they generate from)" (Sewell, 1992:22). Practices are therefore enabled as well as constrained by social structure, and these practices in turn make the transformation as well as the continuity of social structure possible. Parents' everyday teaching practices such as the types of knowledge selected by parents, their children's expected responsibilities and privileges, and the descriptions of children's "good" and "dissatisfying" performances (which reflect their core values) are enabled and constrained by what facilities are around the parents, what methods are favored by the mainstream culture (for example, what they see from the mass media), what parents can afford to do, what parents' peer groups are doing, and how parents cope with their children's school curriculum.

In my 24 interviews, there were two channels through which parents taught their children engineering-related knowledge: material resources and daily interactions. These two channels are not necessarily mutually exclusive. The most commonly used material resources were manipulative toys, computer programs, websites, books (either literature or science oriented), TV programs and DVDs, and trips to museums or exhibitions. The use of these resources is largely determined by the manufacturing and consumption preferences of the society, distribution of knowledge and skills, relationship between explicit concepts and skills learned from school and their financial reward as well as social reward, access to the resources due to the parents' social class, parents' financial ability, household locality, and the children's age, gender, birth order, and their assumed personality. For example, the parents' financial ability decides what types of toys are prioritized and for what purpose the parents are buying the toys. Laura, one of the parents who participated in the study, mentioned that she used Barbie dolls as tools to help her daughter practice counting when she was two years old. In contrast, imagine a low-income family with many children. Here, the parents might use objects that are more practical and affordable or objects already in their possession. The purpose of buying a Barbie doll is different, too. For a low-income family, parents may buy their children a Barbie doll based on their wish to provide their children a toy that other children possess. In contrast, Laura might have multiple distinct considerations. For example, a different Barbie doll would increase the variety of toys for her children, and the toy itself can be used as a teaching strategy (and Barbie's latest career as software engineer, though announced after my study concluded, may provide yet another opportunity for parents to teach their children engineering concepts).

Another channel through which parents teach their children engineering concepts is in daily interactions. Some parents take 10 to 20 minutes every night to answer some questions before their child goes to bed, usually involving curious questions about nature. In doing so, they claim to encourage their children's curiosity, a characteristic that is highly valued in a middle class American family with both parents systematically trained and well educated. Some parents invented a mini project such as building an electric circuit or fixing an old computer to engage their children in the problem-solving process in a "natural" environment. Most parents have taken their children to work on occasion, and some of them have incidentally introduced their children to specific objects they use at work. According to the Neo-Marxist conflict theory (Collins, 1985), such a way to organize interactions reflects the social status group of the parents. Additionally, through associations with members in the same group, the parents share common status cultures such as language styles, parenting styles, requirements for education, interpersonal dynamics, values, and topics (Collins, 1985:101). Such ways in which educational interactions take place make it possible for the children to become technologically capable, curious, creative, and able to fix problems. These are expectations that overlap in both the macro American culture and the engineering culture specifically and are constructed under social structures. In meeting the expectations, the social structure in turn is reinforced.

The above analysis is not to imply that these parents – who share similar social statuses, academic backgrounds, parenting styles, and expectations for children - are homogenous as a group. The knowledge these parents choose to pass on to their children through selected strategies reflect the integrated core values of 1) the mainstream Anglo-American culture, 2) the microscopic engineering culture, 3) various subcultures (race, gender, nationality...), and 4) the parents' historical experiences. For example, students in American culture are encouraged to take initiative and be motivated to learn. Students are expected actively to ask questions and participate in class discussions and other activities; they are frequently rewarded for contributing to the class and giving critical and constructive ideas (Pai and Adler 2001:221). Self-motivation, independence, curiosity, and creativeness are considered as desirable qualities (Pai and Adler 2001). Children are expected to reflect such qualities as well.

Liz, who is a professor teaching biomedical engineering, complained that her son doesn't have much initiative to learn. When we asked her to describe her son, she carefully said that her son is "different" from other children in the sense that he doesn't seem to have a lot of curiosity, and he doesn't ask a lot of questions. Liz's worry came from the awareness that her son doesn't have some of those core values that are preferred by this society: curiosity and initiative. While every other child is praised for being curious, Liz is concerned that her son's passive learning style will not help him succeed. As Ann Swidler (2001) postulated, social structure depends on the mutual reproduction of schemas and resources. Schemas are the semiotic codes shared by a group of people and used by them to make sense of the world. A schema is what makes a resource meaningful as a resource (2001: 78). Take our parent study as an example. These parents with engineering backgrounds are well educated by formal institutions with at least a Masters degree, while some have a Ph.D. The engineering schemas – such as solving an engineering problem – that are deeply embedded in heavily scripted engineering classroom interactions are internalized. Thus when parents who share the same engineering schemas see a child taking a toy apart, they think of the action as initiating a problem which leads to the next step – putting the toy back together. However, parents who don't share the same schemas are more likely to blame their children for breaking the toy and mentioning the financial repercussions. The schemas parents internalized during their own learning process became the rationale they used to interpret resources and interact with their children who in turn learned to interpret things by using the same schemas. With the ongoing mutual reproduction of resources and schemas, the social structure is sustained.

Different parenting styles may also be attributed to different sub-cultural backgrounds. Aaron, who is a professor, described how he took his son down to their basement and explained to him the structure and functions of the water pipes. Laura, who is a Chinese woman pursuing her Ph.D. in America, says that she is not very satisfied with the mathematics education here. "There's too much play-work here in American elementary schools," she said, "I still think the Chinese way is better." She gave her children math exercises and graded them like a teacher. Our interviews suggest that parents within engineering fields but with different specializations have different understandings of what engineering is and therefore have different focuses about teaching what they think is engineering-related. Parents who see engineering as problem-solving are more inclined to initiate a small project to get their children involved, and the focus is on how things work. One parent who called herself a "soft engineer" (which is generally associated with problem-solving, design, communication skills, and teamwork) focused more on the basic scientific and numerical skills that she thinks are fundamental and crucial to engineering.

Tom, who has worked in industry for a long period of time (as opposed to other parents who are in academia) believes that engineering is not always problem-solving but most of the times is just maintenance, or to "keep the machine running". However, his teaching strategies did not seem to be too different. According to Durkheim's social order theory (Durkheim 1922), the study of social structure focuses on the moral order, the central value system, that, though created by people, has an independent and external existence and acts as a constraining and conditioning force upon individual people (Meighan and Sirah-Blatchford's 2003: 252). Parsons (1951), like Durkheim, believed that social order is achieved through the operation of an integrating system common to all members of society; yet he also emphasized how individuals constantly adjust themselves through scrutinizing the process of socialization. Looking at the relationship between tacit knowledge and subjectivity from the perspective of social structures thus helps us understand 1) that parents' educational practices are shaped by the basic principles of their commonsense knowledge, 2) that their ideology of education functions as to ensure the commonsense knowledge to be put in their daily practices and obeyed, 3) how different social systems such as families, engineers, and different ethnic groups are integrated, 4) how individual parents justify their practices through scrutiny, and 5) how through the interaction between individual parents and the society, both the parents' goals and the social expectations become realized. Further, the integration of structural analysis, cultural analysis, and Swidler's understanding of structure as the mutual reproduction of schemas and resources provides us a different perspective that gives meaning to parents' teaching activities. Therefore, I do not only focus on the relationship between individuals and society, but also the meaning of individual practices under certain schemas constructed by the members of the society (for example, a child taking a toy apart is perceived by engineer parents as an aspect of curiosity and an initiatial step to problem fixing).

However, the study of social structure and culture focuses on the relatively stable features of behavior and context and the patterned arrangement of relationships among individuals and groups while leaving the problem of process unaddressed. How do these schemas come into being? How do parents reorganize the messy and conflicting knowledge from different levels of social systems and transmit the knowledge to the next generation? Under what specific situations are these subjectivities taken up? What emotions, feelings, desires, and perceptions are these parents going through while making their most trivial decisions of what to teach and how to teach? In the following case study, I delve into these processes by analyzing a specific interview with a female engineer who seemed to represent both the conflicts and the integration of all kinds of knowledge she was trying to pass to her children.

Engineering Teaching on the Micro Level

This case study centers on an interview with a female engineer parent, Laura. In order to better reveal the process of intergenerational knowledge transmission in which Laura tried to put different pieces of knowledge (engineering knowledge, Laura's own cultural background, and Laura's perception of mainstream American culture) together, I follow Hansen's suggestion by dividing the following analysis into several steps. These steps will help our understanding of how the social structures are created, maintained, challenged, and modified over time as well as necessary to his/her changing environment (Hansen, 1990: 192). The steps are: 1) the definition of the situation; 2) the cultural significance associated with communication channels used to encode and decode communications; 3) the interplay among channels of transmission; 4) the communicative-interpretive repertoires of participants, including communicative competence in the codes being used, 5) the communicative strategies participants used to realize their respective interests and purpose, and 6) the role and identity attributions.

Laura is a Chinese woman pursuing her Ph.D. degree in engineering, specializing in software programming, computer networks, and information security. Her husband is also an engineer and is currently working in industry. Prior to pursuing her Ph.D., Laura had eight years of industry experience. Laura has two children, a ten-year-old son and an eight-year-old daughter. In the following conversation, you will see Laura trying to tell me what kind of engineering-related knowledge she taught her children. She also stated that she was a "soft engineer" and that many things she had to do at work are math related. Therefore, she viewed math as fundamental for engineering.

> Interviewer: "So you started doing that after they have learned some math at school?"
> Laura: "yes. Uut, actually , their math, uh-mostly, I uh taught them math because their math is more advanced than what they are learning at school? [Interviewer: uh-hmm] So I uh, the-, they learned their math at home, basically." ((chuckle))
> Interviewer: "Oh, OK. So-"
> Laura: "Schools, especially middle schools here are not too demanding here in America? I would say American education here, eh- even in the best middle schools here (the name of the location is omitted for confidential reasons), I know a lot of parents, the way they teach math, I think it's not demanding enough, so that if I don't teach them at home, I feel like their talent will get wasted. So ((chuckle)), that's how I feel."
> Interviewer: "So are there other ways in which you tried to explain math to them?"
> Laura: "Um, see, uh-here in America, we like to say let's play games and do math. [Interviewer: uh-hmm] And we don't do it that way. I do it in the Chinese way. I came from China, and I, and I-learned my way there. Ah-I teach them Chinese way ((laugh))"
> Interviewer: "[OK. So it's kinda like complementary-"
> Laura: "[yeah I thought it was very important". ((laugh)) "I actually think the Chinese way of teaching math is better? " ((laugh))

According to her description, her definition of the current situation was that she was not satisfied with both the depth of the math education in America in general and the play-work teaching strategies she has observed from other parents and schools; the school was wasting her children's talent. She expected that teaching her children math the Chinese way would keep her children from falling behind where they were supposed to be had they been raised in China. Apparently, there are two conflicting communicative channels that are associated with two different cultures. One channel is associated with mainstream American culture and stresses the importance of autonomous study, independence, initiative, and having fun, especially at the level of elementary school. The other channel through which the knowledge is transmitted is associated with Chinese culture which values cooperative study, passiveness (for example, students are expected to follow the guidance and authority and learn through watching, listening, and emulating), knowledge memorization, and heavy homework. In general, American school personnel believe schooling to be a process of developing the whole person (Pai and Adler, 2001:220- 223). Thus non-academic activities are considered an important part of schooling. Playing, for example, is perceived as a strategy to initiate children's curiosity to learn as well as a way to develop the children's social skills. As Spindler and Spindler (1990:37) generalized, one of the core values of the Anglo-American society is a sociable, easy-going orientation. The ideology of early children's education is also to explore and support their own interests instead of pushing them in any one direction (which is almost a taboo in the interviews with *parents).* However, in a Chinese mom's eyes, playing at school – where only academic related activities are supposed to take place – can be a distraction to the child's intellectual training and cause anxiety for the mother.

Being a Chinese mom, Laura also expected her children to be among the top students in their classes. Even though she claimed that she didn't intend to push her children, she was very proud when she told me that her son had won several math competitions, and her daughter – who didn't show very much enthusiasm in math – was a year ahead of her classmates. Facing this anxiety, Laura felt the impulse to change the situation. She then went on to tell me how she achieved this change. Another channel through which Laura taught her children engineering-related knowledge is associated with the history of her engineering learning process. Most of Laura's education was done in China where she also had eight years of experience working in the engineering industry. As she is currently studying for her Ph.D. in engineering in an American institution, she has also internalized the core engineering values in the U.S. through her learning practices. Her perspective of what engineering is can be very different from the mainstream perspectives as we shall see below:

> Laura: (My daughter)"-She's very self sufficient,? She, she, she cooks her own pancakes?" ((chuckle))
> Interviewer: "[Ah"
> Laura:" [So we think that would related to engineering. you wouldn't think cooking and engineering (are related), but engineering, uh, you follow a direction, mix the eggs and flour together, ((laugh)) [Interviewer: right]. I think that'll will be good"

Interviewer: "[It's a, i-it's a process of production?"
Laura: "Right. Production. And also you know the modern grinder, the mixer. So 'cause grandma has to do it by hands, she does it by hand. And with the mixer, they know this is the, because there is engineer (ing)."

The above conversation shows that engineering is perceived by Laura as a symbol with two meanings: 1) engineering is to "follow a direction" or follow instructions, and 2) engineering is to design innovations which improve our lives. The second meaning is a commonly shared meaning within the American engineering culture, whereas the first one is gained from Laura's history of learning and working in China. While the second meaning is articulated frequently and almost throughout the entire interview, it is the first meaning of engineering – follow the instruction – that Laura uses to construct her real parenting practices. For example, feeling the anxiety that the school is not demanding enough in the teaching of math, Laura brought home numerous math practice sheets for her children to work on, and "I grade them like a teacher," she said. If the children did the problems wrong, she would circle the wrong answers and ask them to redo the questions. Laura also bought her children the Stanford EPGY (Educational Program for Gifted Youth), a computer based program for math, and asked them to practice by following the program's instructions at least half an hour each day. Both solutions consist of two types of instruction: one is to follow Laura's own instruction to finish the work she gave to her children, the other one is to study math by following the instruction of the program. When asked about what she usually taught her children, just like all of the other parents I have interviewed, Laura felt the necessity to immediately claim that she didn't really teach her children anything specific because she wanted her children to be free to choose what they like to do. However, in the later description of how her daughter learned math, she first showed some dissatisfaction since her daughter wasn't as motivated to learn math as her son; she then said she felt lucky because her daughter doesn't really hate math even though she didn't show much enthusiasm; at last, she was proud to say that her daughter, although not as successful as her son, was still doing very well at math and her level was one year more advanced than her peers.

Therefore, by articulating what is expected by mainstream society and then actually practicing under completely opposite schemas, the social values are sustained and Laura's personal purpose is realized. Laura also did not have to be fully conscious during the process of readjustment. As I have shown above, the interview with Laura was full of contradictions. As a self-selected participant, she was attracted by our flyer looking for parents who transmitted engineering knowledge to their next generation and told us that this project was interesting. She might have been interested in our project for two possible reasons: 1) our requirement of participants confirmed her self-presentation with multiple identities – a mom, an engineer, and a responsible mom (for she provides "good" education to her children), and 2) she hopes our research will provide more learning opportunities. Each reason implies her will to expose her children to engineering knowledge. However, she came to me and claimed that she had never intentionally taught her children anything specifically about engineering like almost every other participant does. She tried very hard to leave an impression that she is a good mom and therefore will give her children enough freedom to explore what their interests are and be supportive. However, this concept of a good mom is challenged when she saw her children doing activities that are non-academic and thought such activities might hinder her children's potential to become successful, for being a good mom also means having successful children. It is possible that she did not teach her children engineering knowledge specifically as she stated, yet the fact that she was attracted to our research was a self-presentation as an engineer who is self reflexive and aware of the many benefits our society has credited to the engineering field.

As shown above, when unfolding the process of knowledge transmission it is important to understand the definition of the situation (what is happening, who is present, and what is expected to happen next), the interactions among different channels through which the knowledge is transmitted, how individuals either consciously or sub-consciously manipulate the meanings associated with different social groups, and the process of role-making within such situations. It is in people's interactions that we find things meaningful.

CHAPTER V: AN INDIVIDUAL APPROACH TO PRACTICE THEORY

The Problem of Problem-Solving

During my interviews with parents, I asked them what engineering meant to them. Out of all the various answers I received, problem-solving was one of the most common answers associated with the knowledge of engineering. Marco, who works for a company in Germany, is currently doing a project in the U.S. as a Ph.D. student in electrical and computer engineering. He's also working on his dissertation which is based on this project with an ENE professor. Marco is one of the participants who had an interestingly complicated background before his pursuit of academic goals. Prior to pursuing his Ph.D., he received a Masters degree in engineering as well as an MBA. Marco also had management experience working a few years in Germany's industry. At that time, he visited universities to recruit students for his company and made his decision to continue his Ph.D. here in America.

I knew Marco through an ENE professor who told me that he might be interested in my project. Due to the time constraint, I asked him directly what engineering meant to him without beating around the bush. To respond, he also answered in a very direct and standard way (as almost every other participant has answered) – it's problem-solving, design, math, and science. I then asked him to use a specific example to explain what he meant by saying that engineering is problem-solving, design, math, and science. Concepts of problem-solving then came up, as I quote from his interview:

> Marco, "Yeah, I was talking about the design. There for instance you have an engineering problem, but there are similar techniques for solving the problem. I know that some of the techniques by the auto engineers could be used. But the problem you have in the auto industry, in the auto industry you look for a cheaper solution. Everybody that cost more, that customers are not willing to pay more. So that means that you don't have this money constraint. And unless you have supercomputers, more powerful

> computers who can do the calculating, you know tracking, things like that. In cars you can have just a small ECU. So that means that no the best algorithm will be adequate for the auto, for the car. So you have to use your judgment, you have to use engineering you have to use all your training, to come with the best solution, with the optimal solution, in some sense. In engineering you are always optimizing things. [INTERVIEWER: "Optimizing things-"] Optimizing, Yeah I would put it in this way yeah. You have to do something but it has to be optimal. Yeah, even if something is going to come…"

What Marco really was talking about here was how to optimize utilities. He used concepts such as problem-solving, design, and math to express a completely different meaning. The concepts that were institutionalized and taught to him were used by him in a discourse to communicate with his coworkers who share the same terminology, take the same terms for granted, understand what he says, and yet might also have their own use of the terms behind which there could be very different meanings.

However, Jeff, who is currently working in industry on management devices for appliances (mostly electric cooling) in mechanical engineering, has a completely different interpretation of problem-solving, which he also views as the core of engineering. When I asked him how he demonstrated the concept of problem-solving to his children, his examples almost all stemmed from machine-related experiences. For Jeff, problems exist everywhere and all the time. Identifying the problem lies in the most mundane and meticulous daily inspection. The problems are where the dangers lie. To solve the problem is as simple as keeping the machine running safely.

> Jeff, "But, uh, roller coasters, I've found, are really good, you know, both from the standpoint of um– and just generally how they work you know – you get dragged up and you conserve energy and you, you go faster and slower – but also from the standpoint of safety. You know, some engineer thought about every single turn in this thing."… "(Be)cause sometimes when kids get on new rides and things like that that go fast, they're very worried about their own safety. And sometimes it's hard to – it's been hard to get them to come on the ride initially. And so if you explain, well you know, an engineer sat down and, uh, studied all these turns and you know, did a lot of uh, simulation and solved equations and they made sure it was safe. And they wouldn't let people go on it unless it was safe."

AJ is one of my best friends from the department. Born on a small farm in China, he has always been prideful of his status of being a "farmer's son" as well as a communist, fighting vigorously against all the recent criticisms about the Chinese government and Chinese policies, whether it be about "Free Tibet" or the current "Google" censorship issue. His defense doesn't always come without admitting that there exist problems with the way the Chinese government handles some of these issues. His disagreement, however, stems from the fact that he identifies a different problem with the Chinese government, a problem he also observes in engineering education in China. For AJ, China's rapidly growing GDP together with its political and military power has made it a country competing with and constantly threatening the U.S. and its alliances whose economics, politics, and societies are, like the U.S. itself, deeply rooted in Western culture. The Chinese government's problem is neither the events themselves ("every government makes mistakes, so does the Chinese government. It's such a young government," as quoted from AJ) nor the degree of democracy or freedom because these are "all cultural differences". To AJ, the problem lies in the deep misunderstanding of Chinese culture from the Western countries – the "post colonizers" – and the Chinese criticizers who misuse western concepts such as "freedom" and "democracy" by trying to apply them to Chinese situations without making any changes ("they think anything Western is more sophisticated and scientific" as I paraphrase); this is due to their shallow understanding of both Western and Chinese cultures.

AJ identifies the same problem in engineering education. He thinks that the biggest problem of engineering education in China is that educators fail to identify that there are cultural differences. He told me that engineering educators in China are trying to exactly copy what is done in the West, and that creates problems. For AJ, Chinese engineers have to practice engineering in their own way, and simply applying Western concepts shows a shallow understanding of both Chinese culture and engineering knowledge. For AJ, to solve the problem means establishing an engineering discipline with Chinese characteristics (which sounds strikingly similar to the Chinese propaganda that was implanted in the brain of every Chinese of my generation and older – "We are building socialism with Chinese characteristics"). Culture, in his sense, is a more concrete and ideal state which is mutually exclusive to other cultures; the ignorance and misunderstanding of cultures will cause serious problems. It is, in AJ's analysis, like a house that is built in a Chinese fashion but with furniture in a different style – the furniture has to morph into a somewhat Chinese style, too. Terms such as "democracy" and "freedom" are like authentic Western furniture in a Chinese house that doesn't match the house's style and therefore causes problems. For AJ, critics believe the house should change styles to make it look just like other Western houses instead of changing the furniture itself. His solution to the problem is to change the furniture, mix it with Chinese styles, and keep the Chinese flavor of the house.

"Site" and Problem-Solving

In this section, I wish to borrow Arjun Appadurai's concept of "site" (1990:7) to further discuss how a seemingly fixed concept, problem-solving, can have different meanings when it is viewed through different lenses: for 1) a "site" does not only emerge when culture flows occur *globally* but also when a subject is negotiating contested cultural ideas and conflicted situations; and 2) globalization in one way or another is always going to be inevitable in institutions and in industry. In Appadurai's "Disjunctures and Difference in the Global Economy" *(1990:7)*, "site" is a place from which subjects view different "cultural landscapes" – a more outward approach to anthropological understanding. He emphasized five different "global cultural flows" or "-scapes" and how the disjuncture between them produces "imagined worlds".

The first, the "ethnoscape", is described as the variety of people in an area, their relation to it (native, tourist, immigrant), and in general the human movement of a landscape. The "technoscape" describes the flow of information and technology, while the "financescape" deals with the distribution and flow of global capital. "Mediascapes" and "ideoscapes" are usually closely related because the "mediascape", or the availability and variety of news sources, provides an outlet for "ideoscapes" to be played out on. "Ideoscapes" deal with the political philosophies of states and movements, and these along with the other four "-scapes" can be applied to understanding all different connotations of the term problem-solving (Appadurai 1996:

50-53, Tsing 2005: 109-120). These processes have disjunctive relationships, what Tsing might call "friction", which produces the "imagined worlds" that people live in.

In Akhil Gupta and James Ferguson's work (1992: 17), "site" has more focus on location. They understood "sites" as imagined communities attached to imagined places because "cultures and peoples, however persistent they may be, cease to be plausibly identifiable as spots on the map". To Peter Metcalf's understanding, "site has the advantage of leaving open the possibility that a variety of cultural practices may coexist there, and of which may or may not extend beyond the site" (Metcalf 2001:65). Metcalf seems to be more inclined to adopt Appadurai's understanding of site which, although blurry, could be theoretically extended as the internal state of individual of the community upon which one perceives disjunctures. "Site" in this sense is more of a "spatial metaphor" and thus unique. As Appadurai (1990:7) postulates, "indeed the individual actor is the last locus of the perspectival set of landscapes, for these landscapes are eventually navigated by agents who both experience and constitute larger formations, in part by their own sense of what these landscapes offer".

The five dimensions of global cultural flow offered by Appadurai and his contemporaries is a methodology that provides a systemic way to look at the messy interactions among global cultures. By dividing global culture flow into five channels, we are able to understand how each of them may be different as its carrier, the actor, moves from place to place. When each of the old (foreign) "-scapes" are carried to a new place, it encounters new (local) "-scapes", and an imagined world is created through constant negotiation and combination of the two – the old and the new, the foreign and the local. However, as a reader of Appadurai and his contemporaries, it is never my intention to reproduce the elaboration of the five "-scapes" as a set of closed paradigms that might a) over-emphasize the motion of the culture flow, yet overlook the process of the cultural reproduction, and b) view the "-scapes" as five separated categories.

On the one hand, globalization is not only culture flowing from place to place but also the reproduction of a culture in one locality. For example, the "old fashioned" American songs favored by the contemporary Pilipino (Appadurai, 1990: 11) is a reproduction of the meaning behind the songs after their flow to the Philippines had already taken place. Despite how cultures flow globally, we also need to understand what happens afterwards, how cultures change and maintain themselves in different places while there are ceaseless "imports" and "exports". On the other hand, the five "-scapes" are most often found entangled as a mixture when disjunctures occur, and neither the observer nor the participant can tell from which exact "-scape" the disjuntures emerge. For example, the disjunctures between Marco's and Jeff's perspectives of what problem-solving is might arise from many differences between them, including their professional backgrounds (MBA, electrical computer engineering, and mechanical engineering), their cultural backgrounds, the different emotions that are imbued in their fields, and their past experiences which altogether would be too assertive to be categorized into any of the five "-scapes".

I will stress the concept of "site" a bit further, for it will help us with a deep understanding of the multi-practice that we see on the site of problem-solving. The concepts of site and landscapes have revealed the subjectivity of a seemingly fixed and objective reality – an imagined space that is objectified and taken for granted as though it truly existed. For example, there is no doubt that problem-solving is the core of the field of engineering to both Marco and Jeff as well as many other engineers with whom I have talked; the engineers not only practice problem-solving in their professional worlds but also apply it to their daily lives as a strategy to make sense out of mundane and trivial events. However, the concept of problem-solving has different connotations as it is practiced by different persons – to Marco, it is optimizing the utilities to benefit efficiencies; and to Jeff, it is to ensure the safety of everyday life. Marco, who holds a MBA degree and is working in a managerial position while studying for his Ph.D., has a different understanding of what is more valuable during the operations of problem-solving, and that is to keep the business running and profit from it.

Optimizing the utilities helps cut costs and save energy, eventually achieving the business goal. It is a strategy used, consciously or unconsciously, to coordinate Marco's understanding of the engineering world with his encounter with the concept of problem-solving and make sense out of it. That problem-solving is to "optimize the utilities" is a landscape perceived by Marco and private to Marco. The same applies to Jeff whose previous experience with engineering is mechanical engineering, inevitably exposing him to a fair number of safety issues. To Jeff, problem-solving is a channel through which he views a landscape of how machines run in daily life, how he practices daily inspections of machine security, and how he resolves safety issues. Both "optimizing utilities" and "ensuring the safety" are problem-solving and true to whomever believes in them. The existence of problem-solving in turn becomes realized through whatever landscapes the actors can vision and whatever practice they may undertake.

Engineering Cultures

In this section, I look beyond the various notions of problems-solving and discuss the historical formation and social contexts of the engineering field in Europe and the U.S. as well as the dispositions the engineers take up in different disciplines, both of which might have contributed to the understandings and practices of problem-solving.

Based on Bourdieu's theory of the scientific field (Bourdieu, 1976), each discipline in the field has its own defining structural position. The relative autonomy of a discipline varies from discipline to discipline and depends on a discipline's ability to refract demands from outside. According to Monte Calvert's own monograph (1967: 62), *The mechanical engineering in America, 1983 – 1910,* mechanical engineering students experienced the struggles between two cultures during their education – "school and shop – for control of the whole process of socialization, education, and professionalization". On one hand, the shop culture leaders were class-conscious elites within exclusive family networks who advocated practical shop work and produced machinists without much training in theory and research. On the other hand, the school culture whose college programs had brought up many young men from lower social statuses to higher ones focused more on engineering analysis, theoretical science, and original research.

This struggle is not unique to mechanical engineering; it also occurs to other engineering fields. As David (Noble, 1977: 57) described, the trend towards the use of scientific investigation and the emphasis on mathematics and physics starting in the 1980s has intensified the tension between the two schools – engineering of "rule-of-thumb" and "cut-and-try", and the "scientific-oriented" and "hypothetical" engineering. According to Noble, this gap is a result of the fact that the majority of the engineering schools were established not as extensions of industries but rather as extensions of schools of science in state and private universities.

In my interviews, these two schools of engineering can still be seen from the various engineering concepts perceived by the parents. When asked to generalize what engineering is, answers vary from theoretical emphasis such as "science and math", "explanation behind everything", "design", and "reasoning skills" to the practical emphasis such as problem-solving, "how things work", "keep things going", and "fixing stuff". Sometimes parents put more emphasis on the theoretical and scientific side of engineering, sometimes more emphasis was placed on the practical side. However, most of the time I observed integrations of the two along with some newly emerged concepts such as "multi-disciplinary", "global environment", and "social relevance".

Meanwhile, historical formations have helped construct the various traditions of the engineering field in different societies. Historically, engineers had to struggle for the recognition of their field as a scientific discipline and its integration into the academy (See Gilbert 2008), especially in the German speaking parts of Europe.

While American engineering societies were struggling with the institutionalization of engineering disciplines in higher education by the end of the 19th century, the American style of engineering emerged and developed quickly as a reference outside of science. Hence, up to the present, engineering disciplines maintained a contradictory relation to the scientific field. At the same time, American schools had abandoned the British "on-the-job" style and the French theoretical style and became less focused on "strength", "permanency", "aesthetic appeal", and "safety". Instead, the American style further emphasized "reducing labor costs" and "economy of construction" (Reynolds, 1991:23). As a result, mechanical engineering (founded in 1880), being one the four earliest engineering societies established in the States – civil engineering (1867), mining engineering (1871), and electrical engineering (1884) being the others – is clearly positioned on the engineering pole (as appose to science) and has a strong historical link to the national machine industry and the concomitant professional field.

Despite the theory-practicality struggle that each engineering discipline shares with each other, each discipline has its own set of dispositions that are different yet not exclusive from the other disciplines. For example, as mentioned above, disciplines such as mechanical engineering and civil engineering have a stronger emphasis on the practicality and the "field culture". On the other hand, materials engineering (AJ's major for his MS previous to ENE) and electrical computer engineering, as relatively younger fields, might have very different dynamics. As Ann Francoise Gilbert's research (2008: 3) in Switzerland shows, educational knowledge is characterized in mechanical engineering classes by a strong classification of knowledge content implying strong boundary maintenance, whereas educational knowledge in material engineering classes is more integrated with the subordination of previously insulated subjects or courses to some relational idea, blurring the boundaries between the subjects.

Coming back to the question of problem-solving, each problem-solving practitioner has his/her own understanding of the concept itself and his/her own way to achieve the goal as shown in previous sections. Let's then review what problem-solving means for Marco and for Jeff. For Marco, the problem is the utility cost during the operation; to solve the problem is to design a way to optimize the benefit. For Jeff, the problem is the security of the daily engineering projects, whether it's a big problem (for example, building construction) or a small problem (for example, driving a car). To solve a problem, an engineer needs to perform daily inspection of the machines and "keep them operating" in a safe mode. From Marco's and Jeff's answers, we can see the traditional emphasis on safety and permanency of the European school of engineering as well as the emphasis on the economy of construction from the relatively new school of engineering in the United States. We can also see the struggles as well as the integrations of the scientific and practical sides of engineering that have always existed in the engineering field. Drawn from the interviews, to optimize the benefit, one needs mathematics and designing skills; whereas to resolve the safety issue, one needs to be familiar with operations of machines and be able to fix any problems. These various concepts of problem-solving and how they should be achieved are the internalized engineering cultures within which and constrained by which the engineers reflexively choose to maintain or change certain practices. Having noticed that, however, by no means can we simply put Marco or Jeff into any category, such as the European school of engineering or the traditional American style of mechanical engineering, nor can we draw simple conclusions that relate any type of engineering background to specific understandings of what engineering is, for to do so is to assume that these engineering disciplines are exclusive to each other and that there are concrete distinctions between them.

On a microscopic scale, none of us live within one single form of culture. Rather, we live within multiple subcultures – what we do and how we make decisions and judgments depends on different dynamics we have between and among our family members, co-workers, schoolmates, and people with whom we are in a close relationship, which all together partially defines who we are. Even in making trivial decisions, we run through a complicated process of negotiation among multiple contesting or similar ideologies within which ideas and dispositions constantly get exchanged. On the one hand, engineering disciplines are not exclusive to each other but are constantly influencing, cooperating, and competing with each other. The boundaries of these disciplines are often blurred due to the natural discursive relationships between them. The engineers, on the other hand, do not live in a engineering environment vacuum, either, but move from one environment to another. Marco, for example, was born and raised in Mexico, finished his Masters in electrical computer engineering in the U.S., and received an MBA degree while he was working in Germany. He is now back in the U.S. in a Ph.D. program continuing electrical computer engineering while working on his project with a professor from the engineering education department. Aside from all the information I know about Marco, there are also other sides of his "personal history" that have helped shape who he is and contributed to how he makes decisions which are unique to him.

The problem AJ identified is that Chinese people and governments are applying Western concepts to their own issues without making any adjustments, the final purpose being to achieve freedom, democracy, and engineering education (these that originated from Western societies) in China with Chinese characteristics only ("We have to do it in our own way", as quoted from AJ). AJ, however, is an "outlier". He is one of my best friends; I never interviewed him in any sense. All the knowledge I have about him and his perception of problem-solving comes from our interactions, my familiarity with him, and sometimes through arguments which are not always pleasant. While Jeff's and Marco's perceptions of problem-solving are partially reactions to my interview questions and therefore are claims of "explicit knowledge", AJ's demonstrations of problem-solving differ in that they come from natural conversations and are strategic and highly situational. Knowing how prideful he claims to be as a Chinese citizen, a communist, and a farmer's son, this notion of problem-solving seems to occur when AJ senses that the value of his Chinese identity is threatened and can therefore be a strategy used for self defense. As an engineer, AJ may or may not have demonstrated his "explicit knowledge" about problem-solving which may or may not be quite different from what I heard or interpreted. Nonetheless, AJ shows a way that problem-solving can be undertaken differently. Problem-solving was viewed by Jeff and Marco as a more "explicit knowledge", yet the underlying assumptions of which are tacit, constructed within and constrained by certain structures. In comparison, AJ was less aware of his acknowledgement of problem-solving as explicit knowledge. Instead, problem-solving was a strategy that can only be useful in certain situations.

General Findings of Engineering Teaching

Although all parents teach their children engineering-related concepts and skills, the content that they teach their children is diverse (see Table 2.1). Most parents teach their children the most commonly shared habits and concepts of engineering, including problem-solving, ideas of innovation, science, and how things work. Despite these commonly shared values, the engineering concepts and skills that parents teach do vary based on the parents' different cultural and educational backgrounds. For example, parents whose fields are more science-oriented may teach basic science and math and claim that they are engineering concepts. Other parents whose fields are more experience-oriented may teach their children hands-on skills by having their children participate when they fix or build things. For instance, parents with civil engineering backgrounds may teach their children how to build things (for example, a tree house), and parents with mechanical engineering backgrounds may teach their children how everyday machines operate.

Different strategies are used to teach engineering concepts and skills, and these strategies commonly vary based on the parents' backgrounds. These strategies are generally grouped into two basic channels through which engineering is taught: materials and daily interactions. Materials can be obtained in various ways. Some materials can be found in any household and do not require purchasing. For example, items that are either outdated or no longer operable (for example, an old music box or a broken clock) can be given to children for them to take apart to explore their inside mechanics. Other materials can be obtained from outside sources (for example, borrowing DVDs and books from a library) and provided to the children. Other materials, such as Legos, flash cards, tool kits, and mini electric circuits might require purchasing.

Conversations are the commonly used form of daily interactions by parents to teach their children about engineering, and these conversations can be initiated either by parents or children. Some conversations are started by the children but directed by the parents. For example, since Jean's daughter is interested in trucks, Jean sometimes sits at a construction site with her daughter just to watch different trucks driving by. When her daughter comments on the trucks, Jean will start to steer the conversation towards engineering-related topics, with discussions such as "This is a different truck than the one we saw yesterday. It works differently." As the conversation continues, her daughter asks more questions about why and how a particular truck is different, and Jean will try to answer all the questions. Other conversations are initiated by the parents, and these questions usually start with "why" and "what" questions. For example, although Ann complains about her son lacking the curiosity of a "normal" kid, she still tries to inspire her son by asking all kinds of questions, such as "What is that?" and "Do you know why the sky is blue?" Lastly, there are also a few conversations that are begun by the children and directed by the children. These conversations only take place when children are old enough to follow their own interest and seek specific answers for their questions. For example, Julie provided the information her daughter needed when she was asked for her input on how to build a mini bridge for a school project.

Most strategies used to teach engineering – including holding conversations with children, taking things apart with children, and reading books with children – can be implemented by any parent. As one parent said in the interview, "every parent is teaching some sort of engineering". However, there are also strategies used to teach engineering which require parents to have certain engineering backgrounds. For example, some parents occasionally work from home, and when their children ask what they do, they may explain to their children specific engineering-related concepts. Other parents talk to their family members about work at the dining table and later find out that some of the concepts in the conversation were picked up by their children. Additionally, most parents (especially those who work in industry) occasionally take their children to work to expose them to the "real engineering world". Having discussed these findings, I will proceed to analyze why certain concepts are taught in certain ways and what the meanings are behind the concepts in the sections that follow.

CHAPTER VI: CONCLUDING THOUGHTS

As social sciences have evolved, engineering is no longer perceived as a discipline of knowledge only, but also a discipline that increasingly carries social relevance. Engineering is now a field commonly constrained by its social context, whether the context is political power, social structure, cultural convention, or institutional pressure. Engineering in the 21st century does not just teach science and hands-on skills, but it also asks many questions: What is engineering? Who is qualified as an engineer? What should an engineer do? Who has the authority to decide what is and is not engineering? These are the questions that face not only engineers nowadays, but they also concern the people in the field of engineering education who make decisions everyday about what and how engineering should be taught.

I started this study with an interest in what and how engineer parents taught their children about engineering. Anthropological methods were applied in this study to examine engineering teaching as a cultural-, class-, age-, gender-, and disciplinary-specific phenomenon. First, by taking a cultural approach and paying close attention to anthropological and other social theories, this study reflects the current diversity in engineering education. For example, I discussed various understandings of engineering as a discipline with engineer parents and found out what engineering concepts are taught to their children and through what strategies these concepts are taught.

Second, by taking an anthropological approach in this study, I attempted to understand the meanings behind such teaching activities. For example, I examined how the concepts of engineering are realized and reinforced through the parents' habitual practice of teaching engineering. In addition, practice theory contributed to the main analysis of this study in the way it unfolded the circular relationship between structures, cultures, and engineering teaching on the macro level. On the micro level, practice theory was used to investigate individual psychology and social interactions between people in specific engineering-teaching situations.

Further, social science might suggest solutions for problems of engineering education, such as the underrepresentation of women and non-Caucasian engineers. Based on the social theory of occupational inheritance (See Chapter I. See also Mannon and Schreuders 2007: 334), children are more likely to choose engineering as their career if their family members exposed them to engineering-related knowledge. The findings of this study suggest that most of the engineering concepts and skills can be taught by any parent except for a few concepts that require the parent to have an engineering background. Therefore, introducing these engineering concepts and skills to non-engineer parents could increase the exposure of their children to engineering and thus pave their way towards an option of engineering careers.

On the other hand, engineering education provides an interactive platform for researchers to work in multidisciplinary fields of cultural studies and brings new insights into social theories. For example, this study provided new perspectives on practice theory, such as a bridging of the macro-micro gap in the application of practice theory and an individual approach that looks at the individuals' configuration of various cultures in the 21^{st} century.

As this study showed, engineering teaching is a cultural practice. It is the engineers who decide whether to teach or withhold engineering, how and when to teach it, and to whom and for what purposes to teach it. An engineer's background contributes to what he/she as a parent believes to be engineering and influences what will be taught to his/her children as engineering. Engineering teaching therefore is inevitably always going to be practiced in culture and as culture. For anthropology, engineering teaching as a cultural practice opens up new topics to explore as anthropology provides unique perspectives to help better understand engineering teaching.

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APPENDICES

Appendix A: Recruitment Flyer Facsimile

Do you Help Your Children Learn Engineering Concepts?

<u>We are looking for parents:</u>

- with children aged 2-18 years old
- who have an engineering background
- who teach engineering to their children or provide resources or support to their children for learning about engineering

- to participate in an interview for a research study
- to identify ways that children might learning engineering
- to provide more children with early opportunities to learn about engineering

Appendix B: General Interview Questions

- What do you do for living?
- What is your academic background?
- Tell me something about your children (gender, age number of children, age, interests).
- What do you teach your children about engineering?
- How do you teach them engineering?
- How do they react?
- How does engineering background influence/ help parenting?
- How do your children know what you do as an engineer?
- What is your parenting philosophy (expectation, ways of parenting)?
- How would you see yourself as an engineer?

Appendix C: Interview Data

Appendix C.1: Parents' Teaching Contents

Contents that can be taught by parents with any background	Contents that might only be taught by engineer parents

• Skills
  • Figuring out how things work
  • Knowing how to do science and math
  • Being hands-on
  • Building things
  • Fixing things
  • Following instructions
  • Being capable of problem-solving
  • Designing
  • Being able to find out multiple solutions
• Philosophies
  • Serving the world
  • Making life easier and better
  • Inspecting and securing daily lives
	• Philosophies
	  • Balancing between being an engineer and a woman
	  • Perceiving engineering as "part of who I am"

Appendix C.2: Parents' Teaching Strategies

Any parent might:	Engineer parents might:
• Approve/encourage children taking things apart • Explain daily phenomenon to children • Visit museums, libraries with children • Watch DVDs, TV/online programs with children • Ask children inspiring questions • Explore toys (Lego, flash cards, puzzle, tool kits…) • Design mini projects with children • Use exercise sheets for children • Help with children's school projects	• Discuss social rewards and benefits of engineering as a career to children • Take children to work (occasionally) • Socialize children with engineer friends • Present themselves as hardworking but happy engineers

Appendix C.3: An Example – Matt Discusses With His Child How to Build a Deck

Teaching activities	Concepts conveyed by the activities
• Discusses the function and location of the deck	• Design
• Discusses what materials should be used and why	• Problem-solving • Safety concerns
• Discusses the style and appearance of the deck	• Multiple solutions to problem
• Instructs how to use tool kits	• Hands-on
• Instructs how to put things together	• How things work
• Uses physics to explain why things can be put together this way	• Utility of science

Appendix C.4: Parents' Educational Backgrounds

			Degrees		
Interviewees	Ethnicity	Parent	Bachelor	Master	Ph.D.
p01	Asian	Mom	N/A	N/A	Software E
p02	Caucasian	Dad	BSE	Materials E	Materials E
p03	Caucasian	Mom	English	Civil E	Civil E
p04	Caucasian	Mom	Math	Industrial E	Industrial E
p05	Caucasian	Mom	Biomedical E	Biomedical E	Biomedical E
p06	Caucasian	Mom	Mechanical E	Mechanical E	No Ph.D.
p07	Asian	Mom	Biomedical E, Nuclear E	Electronic E	Electronic E
p08	Caucasian	Dad	Computer Science	Computer Science	Computer Science
p09	Asian	Mom	Environmental E	Environmental E	Environmental E
p10	Caucasian	Dad	Electronic E	Science and Technology	Science and Technology
p11	Caucasian	Dad	Physics & Math	Electronic E	Electronic E
p12	Caucasian	Dad	N/A	Mechanical E, Materials E	Civil E, E. Education, Nuclear E
p13	African American	Dad	Mechanical E	Mechanical E, System E	Mechanical E
p14	Asian	Mom	Biochemistry	Environmental E	Environmental E
p15	Caucasian	Dad	Materials E	Materials E	No Ph.D.
p16	Latino	Dad	ECE	Physics, MBA	ECE, E. Education
p17	Caucasian	Dad	English	Electronic E	E. Education
p18	N/A	Mom	Civil E	Civil E	Civil E
p19	Caucasian	Mom	Chemistry	Management	No Ph.D.
p20	Caucasian	Dad	Chemical E	Chemical E,Biomedical E	Chemical E
p21	African American	Dad	Biomedical E	MBA	No Ph.D.
p22	N/A	Dad	Physics	Ocean E	Ocean E
p23	Caucasian	Mom	Electronic E	E. in Manufacturaing Systems	No Ph.D.
p24	Caucasian	Mom	Civil E	No Masters	No Ph.D.

N/A – not applicable, E – Engineering, Biomed – Biomedical, ECE – Electrical and computer engineering

Appendix C.5: Parents' Career Backgrounds and Children's Information

Interviewees	Current Career	Positions	Years in Industry	Gender of Children	Age of Children
p01	Software E	Academia	several	1 boy, 1 girl	10,12
p02	Materials E	Academia	0	1 boy, 1 girl	2.5, 5
p03	Civil E	Academia	10	2 boys, 1 girl	9,14,17
p04	E Education	Academia	0	1 boy, 2 girls	2.5
p05	Biomedical E	Academia		1 girl	3.5
p06	E Education	Academia	10	1 boy, 1 girl	9
p07	Electronic E	Academia	0	2 girls	11, 14
p08	Electronic E	Academia	4	1 girl	5.25
p09	N/A	N/A	0	1 girl	2.5, 3.5
p10	E Education	Academia	3	1 girl	4.5
p11	ECE	Academia		2 boys	17,20
p12	Engineering Education	Academia	3 summers	1 boy, 2 girls	15, 10, 3
p13	Mechanical E	Industry	5\6	1 boy, 2 girls	6,9,11
p14	Environmental E	Academia	0	1 girl	5
p15	Metallurgical E, Materials E, Process E	Industry	8	1 boy, 1 girl	2.5, 5.5
p16	N/A	N/A	8\9	2 boys, 1 girl	3.5, 8
p17	Electronic E	Academia	30	3 boys, 5 girls	6,17,19,21,23,25,?,29
p18	Civil E	Academia	0	2 bys	17mons,5
p19	Chemical E, Management	Industry	25	2 boys	15, 19
p20	Management	Industry	25	2 boys	11,18
p21	Biomedical E, Management	Industry	15	2 boys, 1 girl	12, 14, 20
p22	Industrial E	Academia	N	1 boy, 1 girl	8,4
p23	Occupant Sensing Systems	Industry	27	2 boys, 2 girls	9,14,16,19
p24	Consulting E, Civil E	Industry	N	2 boys, 1 girl	10, 5, 1

N/A – not applicable, E – Engineering, Biomed – Biomedical, ECE – Electrical and computer engineering