Visualizing identity:
Perspectives on the influences of digital representation in architectural practice and education

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A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Science in Architecture

University of Washington

2013

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Abstract

Visualizing identity: Perspectives on the influences of digital representation in architectural practice and education

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Being an architect today is not the same as it was twenty years ago. The discipline of architecture continues to be influenced by the use of technology, specifically digital representation, which in this study refers to the use of software to create virtual three-dimensional models. Digital representation continues to grow in use in both the profession and in architectural education as the demand for realistic visualization increases. In this changing context, new students and seasoned professionals in architecture find that the identity of an architect has evolved over time to include skills in technology, in addition to the foundational skills based in design thinking. Firms seek talented graduates, students seek the right balance of learning, and educators attempt to bridge the expectations between education and practice. When students learn to be architects, how can technology be integrated with foundational learning to align with professional expectations?

In order to move beyond the previous studies that typically focus on student artifacts as proof of successful technology integration, the framework for analysis of this research is based in sociocultural learning, with a focus on situative motivational theory. The influence of social

context on student learning and ongoing practice is a compelling perspective from which to understand the reasons for change. The communities of professional practice and education exercise influence on each other, and the individual members construct their communities through activity and engagement with each other. Digital representation in professional practice is examined for its influence on student motivations and identity formation in preparation for practice.

Supplemental Materials include interview transcripts, interview summaries, and classroom observation transcripts.

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Acknowledgements

Arriving at my completed thesis has been the work of many. My thanks to the following for their support, criticism, and ready discussions:

- My committee members, for allowing me not only the forum and environment to ask these questions, but also believing that these questions should be asked, and for providing the support and feedback to refine my research.
- The DMG and fellow educators/students. I thank you for your insight, contributions, and collaborations in all things digital, analog, and material as I did my research.
- My family and friends for your never-ending support and understanding for every endeavor.
- The many individuals who participated in this study, both officially and unofficially. Our discipline is a community made up of our knowledge, experiences, identities, and meaning. I thank you for your willingness to let me see your part in it.

Preface

As both an educator and a designer, I have found that the boundaries of professional practice and school are often blurred. Those of us who have felt the call to share our experiences with new designers often discover that teaching for success in both communities is not always simple or straightforward. I asked questions about teaching new designers because the industry of architecture and those who practice in it are both brilliant and constantly evolving, challenging all individuals to push past traditional expectations and to develop new ways of thinking. I wanted to approach teaching and learning the same way that we often approach design, working with others to improve and refine, reflecting on past and present evidence as a basis for future change and development.

While talking with many of the professionals who were interviewed, I found that providing a more thorough background for the study was imperative to candid answers and observations from the respondents. If I first approached them with the identity of a graduate student, they appeared careful to avoid negative observations; once I revealed my prior professional experience in architecture and education, respondents shared both observations and events that included both positive and negative perceptions of digital technology and student skills. I appreciate the collaboration with every individual who sincerely wanted to help improve our industry by providing valuable insight and experiences into the impact of digital representation in architecture.

I hope that the questions I have asked and the conclusions that I have drawn will be a starting point for all individuals to consider how and why we choose our paths into design, and where representation, specifically digital representation, fits into our process and trajectories.

Introduction

What does it mean to be an architect?

Being an architect today is not the same as it was twenty years ago. The discipline of architecture continues to be influenced by the use of technology, specifically digital representation, which in this study refers to the use of software to create virtual three-dimensional models. Digital representation continues to grow in use in both the profession and in architectural education as the demand for realistic visualization increases. In this changing context, new students and seasoned professionals in architecture find that the identity of an architect has evolved over time to include skills in technology, in addition to the foundational skills based in design thinking. This evolution in the architectural skill set creates expectations for individuals in both education and professional practice, as students prepare to work and firms seek to hire. Professionals wonder why students do not sketch; students wonder what software they should be learning. Firms seek talented graduates, students seek the right balance of learning, and educators attempt to bridge the expectations between education and practice. When students learn to be architects, how can technology be integrated with foundational learning to align with professional expectations?

In an effort to uncover strategies to improve digital technology integration in learning, this study seeks to explore how the advances in digital representation have affected professional practice, and how these changes may have influenced student identities in architectural education. The two communities have long influenced each other, as students prepare to become architects, and professional practice seeks specific skills from new graduates. The nature and responsibility of teaching and training architects has historically been a source of tension, as practice interests and pedagogical interests often vary due to context, and these interests may not always align. The consequence of this traditional lack of alignment in interests, while integration of digital technology in education varies widely, there is a perception that the use of technology in design studio has affected student skill (Angulo, Davidson, & Vasquez de Velasco, 2001; Barrow, 2006). This anecdotal observation and its importance to future architectural practice prompted an examination of effects of digital technology in contemporary architecture, specifically the increasing reliance on use of digital representation, where virtual three-dimensional models are built, studied, and manipulated in the design of built structures. As these technologies become more prevalent in practice and education, their influence must be assessed; the training of architects builds skills for the future, and the destiny of the discipline may rest on the outcome of contemporary education.

Due to the prevalence of technology in design, architecture is on the verge of significant change in the practice of designing buildings. The influence of digital representation continues to impact every facet of design and construction at a quick pace, and can force change before individuals are ready for it. Early computer aided design (CAD) systems mimicked traditional hand drafting with computer generated lines that were more easily revised and reproduced than pen on paper; documentation drawings became more efficient and productive. Since 1990, the increased use of CAD in the architecture industry has created conflict in ideas for integration and the appropriate use in design, and the recent addition of Building Information Modeling (BIM) and other digital tools for analysis continue to reshape the ways that architects conceive of buildings, allowing external visualizations in new and dynamic ways.

Through the use of semi-structured interviews with professional practitioners, classroom observations, student surveys, and artifact analysis, the following research explored these questions based on the changes described above: 1) How have advances in digital representation since 1990 changed professional architectural practice and education? 2) Does the use of digital representation influence the skills most valued in these two communities? If so, how? 3) What effect does digital technology use have on perceptions of student capabilities as they enter the profession? 4) How can contemporary education better integrate digital representation to prepare students for professional practice?

In order to move beyond the previous studies that typically focus on student artifacts as proof of successful CAD integration, the framework for analysis of this research is based in sociocultural learning, with a focus on situative motivational theory. The influence of social context on student learning and ongoing practice is a compelling perspective from which to understand the reasons for change; the communities of professional practice and education exercise influence on each other, and the individual members construct their communities through activity and engagement with each other. Digital representation in professional practice is examined for its influence on student motivations and identity formation in preparation for practice.

In Chapter 1, sociocultural theory, communities of practice, and identity are explained and located within the social worlds of both professional practice and education as a framework for this analysis. Chapter 2 reviews current literature documenting observations of technology's influences on architectural practice and education most pertinent to the study. Chapter 3 describes the research design and methodology for data collection and analysis. Chapter 4 presents and interprets the findings, and Chapter 5 provides an analysis of the results in view of meaning and identity in communities of practice. The discussion explores the social practice and context of architecture in the profession and in education, clarifying the use of digital representation in the design process, and demonstrating the formation of identities with learning trajectories that affect future participation in professional practice.

Chapter 1.
Contexts of Practice, Meaning, and Membership

In order to better understand the influence that digital representation exercises on the architectural discipline, this study and analysis are grounded in a framework of sociocultural theory, with an emphasis on Wenger's (1998) model of the community of practice. A lens of learning theory brings into focus the ways that the motivations, tools, and actions of the individuals involved affect their social contexts, and vice versa. An explanation of sociocultural theory and the applicability of key themes to architecture and education follow. These themes include communities of practice, negotiation of meaning, and situative identity formation.

Communities of Practice

Wenger (1998) characterizes a "community of practice" (p.73) as one where participants are mutually engaged in activity. Practice exists because people engage in actions that are meaningful due to the perceptions and importance that they place upon them. This "mutual engagement" results in processes where meaning is negotiated for those involved through both action and interpretation and defines the community. The actions and items required for mutual engagement are essential to the practice, and mutual engagement is required for membership in the community. One must be engaged in order to belong. Each individual participates through the use of resources that have become a part of the "joint enterprise" of the community, described as both a goal and the process of pursuing that goal (Wenger, 1998, p. 77). These resources are "routines, words, tools, ways of doing things, stories, gestures, symbols, genres, actions, or concepts that the community has produced or adopted in the course of its existence, and which have become part of its practice" (Wenger, 1998, p. 83). This collective set of resources is considered the community's "shared repertoire" (Wenger, 1998, p.83).

The architectural discipline's methods, processes, and traditions easily fall into the definition of a community of practice. Whether professional firm or educational studio, each environment and social context carries with it norms and practices that not only define how individuals interact with each other, but that also change based on the individuals involved, the projects assigned, and the tools used within it. Professionals, educators and students are all somehow involved in the joint enterprise of architectural design; the tools used to practice and communicate within the discipline in order to build buildings become the shared repertoire. Within the overall community of architecture, specific separate communities also exist. In each of these smaller communities, the tools of the shared repertoire leading to the joint enterprise of design may be different. For example, the practices in education and professional firms are not identical; in education there is an emphasis on learning design, and in the firm there is an emphasis on doing design. Each community creates and maintains its own practices.

In the concept of a community of practice, the negotiation of meaning is "the process by which we experience the world and our engagement in it as meaningful" (Wenger, 1998, p. 53). Negotiation is based on existing meaning, but relies on current context for ongoing significance. Change in context will influence terms for negotiation, and consequently will change the meaning given to practices and tools in a community. In relation to this study, the meaning of digital representation to practice has been renegotiated over time, changing in both importance and use over the years, in part due to advancements in technology. Participation requires that all members understand what is most significant, or meaningful, within the community's practices (Greeno, 2006). Both the communities of education and professional practice have renegotiated the significance of digital representation for each of their specific contexts through use and importance.

While participation is the basis of membership in a community, the concept of reification describes the negotiation of meaning in an even deeper way. In Wenger's (1998) view, reification "refer[s] to the process of giving form to our experience by producing objects that congeal this experience into 'thingness.' In doing so we create points of focus around which the negotiation of meaning becomes organized" (p.58). This is manifested vividly in the process and documentation of design for architecture: digital documents and models are reifications of ideas; construction documents are reifications of the design process and the final solution, and in terms of digital tools are reifications of the model; finished projects are reifications of construction documents.

Architecture as a discipline in contemporary practice is built around a language of symbolic representation for communication. The design process and its manifestation of design has traditionally employed a system of two-dimensional drawings to express intent for a three-dimensional object, intended to both reveal and interpret the design (Coyne, 1996). A community of practice constantly renegotiates meaning through reification, producing "abstractions, tools, symbols, stories, terms, and concepts that reify something of that practice in a congealed form" and yet "no abstraction, tool, or symbol actually captures in its form the practices in the context of which it contributes to an experience of meaning" (Wenger, 1998, p.59). In that same way, digital representation in contemporary architectural design is a form that reifies the processes involved in conceptualizing and visualizing a building for construction; the digital model gives form to the ideas of the designer, but does not reveal the steps, thinking, or manipulation needed to produce it. For the architectural professional or student, a digital model can mean many things. For either individual, the level of participation and experience in the community of architecture will determine what meaning is attributed to the model. As described further in the study, professional practitioners are able to ascribe materiality and the properties of the constructed project to the digital model; novice users may only be able understand shape and form, not the implications of structure and material.

Reification happens within a community in many ways, and evolves with community actions in negotiation of meaning. The use of a tool will change the nature of the activity and the product it generates, in turn changing the nature of the experience for the individuals involved (Nolen & Ward, 2008; Wenger, 1998). The use of technology has repeatedly influenced the process of design in architecture. Digital representation cannot help but influence the output and processes of architectural practice, as well as the meaning created through the experiences associated with the use and generation of the digital model. In the context of technology, specifically digital representation, architecture negotiates the meaning of representation through its changing purpose; not only does it document and express intent in the two-dimensional manifestation, but in its contemporary use in three-dimensional visualization, digital representation also assists reflection and problem analysis (Abdelhameed, 2004; Chen, 2001; Schon, 1983). In the architectural community of practice, developments in digital representation have enabled users to negotiate new meaning through technological output, a new tool in the shared repertoire.

Individuals become members of a community through their participation in mutual engagement, but this does not always imply direct participation; it may also include other modes of involvement such as conflict, competition, cooperation, or observation (Wenger, 1998). The level at which members participate shapes each individual's experience and the community as a whole (Wenger, 1998). Membership in a community and the terms through which it is acquired involves experience; each experience and its contribution to an individual's sense of self will then also determine the meaning of self within the context of the community (Holland, Lachicotte, Skinner & Cain, 1998; Nolen & Ward, 2008; Wenger, 1998). This negotiated meaning of self is the basis for the concept of identity formation within sociocultural theory. In the practice of architecture, the skills and abilities that are most valued in each community influence the evolving identity of an architect. As the meanings of skills evolve and change in value, so do the ways in which individuals negotiate their own sense of self and belonging within their specific community.

Learning in a Community of Practice

The concept of apprenticeship is often used as an organizing framework for social participation in learning contexts that require high levels of skill (Lave & Wenger, 1991; Wenger, 2000). Environments that incorporate apprenticeship-like learning place the act of knowledge building into a social context that allows participants to experience events in ways that are specifically meaningful in the culture of a "community of practice" (Lave, 1996; Lave & Wenger, 1998; Wenger, 2000). In these contexts, learning occurs through the process of practice, changing the learner by equipping him or her to progressively become a more competent participant in the culture (Lave & Wenger, 1998; Wenger, 2000). Within the context of informal learning through social groups, "collective knowledge is both a social and cognitive endeavor, and the quality of the conversations and nature of the shared engagement mediates how much is learned (Bransford et al., 2006, p. 228).

Architecture has long been a discipline that utilizes apprenticeship types of training for new members to the community. The Intern Development Program (IDP), developed in the 1970's, provides graduates with a formalized training program that requires them to gain required experience under direct supervision of a registered architect before taking the registration board exam and applying for licensure. Intern architects are understood to be in training and development while working in professional practice, but do not yet meet requirements to be architects. Students prepare for this intermediary membership through education in accredited programs. Their educational environment forms the first community in which they must negotiate meaning in the joint enterprise of design. As students move from the educational community to the professional community, they participate in social contexts that provide experiences similar to apprenticeship training, where more knowledgeable mentors provide them with opportunities to learn and providing interpretation and meaning for accepted practices.

Vygotsky (1978) emphasized the importance of society and culture in the promotion of cognitive growth as the basis for sociocultural learning theory (Wertsch, 1988). In this perspective, "learning and development take place in socially and culturally shaped contexts, resulting in changed contexts and opportunities for learning" (John-Steiner & Mahn, 1996, p. 191). Cognitive development occurs during the reciprocal influences of learner and social environment, where a "more capable" other is needed to mediate and interpret accepted social symbols and representations (Vygotsky, 1978, p. 88).

Within the sociocultural perspective, Lave (1996) explained that "learning is an aspect of changing participation in changing 'communities of practice' everywhere" (p. 150), whether formal or informal. In both formal and informal environments, learning is part of doing, and crafting identity is a social process that includes becoming more knowledgeably skilled (Lave, 1996). While studying apprenticeships, Lave (1996) discovered that during the process of learning a craft, "apprentices were learning many complex 'lessons' at once" (p. 151), and underlying social practices, meanings, and relationships were also learned through the "transmission" of culture (Lave, 1996). Apprentices were prepared for the social context of their future occupations through the mediated understandings that masters provided.

Architectural education provides students with their first opportunities to learn cultural norms and expectations for the discipline. Students form identities to include the skills they understand as needed to fulfill the expectations of the discipline. Instructors and other professionals that contribute to the educational context help students to create the social context of learning, and the sense of self and belonging in this community are mediated by all the participants. When students then move on to intern architect positions in professional practice, this new community will then provide a different social context with further learning and development experiences throughout the individual's career (Wauters, 2012).

Situative Approaches to Identity

The situative perspective of motivation includes sociocultural theory in its foundation, where learning occurs within the social context, characterized by participation within a specific culture or community (Hickey & Granade, 2004; McCaslin, 2004; Nolen et al., 2009). Individuals define themselves through their participation in the practices of a community, where the definition of knowledge and its value is constructed not by the individual, but through those practices; competence is defined through the experiences and meanings set by the community (Hickey & Grande, 2004; Wenger, 2000). However, for Hickey and Granade (2004), identity is considered a function only of practice, and does not consider beliefs or values. In contrast, situative theory considers the system made up of individuals and the many facets that comprise the social and physical context, where meaning is both negotiated and co-constructed by the individuals within the system (Nolen & Ward, 2008). It is in this contextual space where individuals form their perception of identity as defined by participation in the community (Nolen & Ward, Wenger, 2000, 2008).

Negotiation of identity is ongoing throughout an individual's participation within a community of practice, and is reconstructed in relation to the various communities with which he or she identifies (Dreier, 1999; Nolen & Ward, 2008; Wenger, 2000). Research conducted with novice teachers (Nolen & Ward, 2008; Nolen et al., 2009) indicated the creation and continuing renegotiation of identity for student teachers as they progressed through their training program. Student teachers valued differing practices based on their current identity and the value that the practices would have in their future discipline; both the meaning of value and the representation of the discipline developed over time as the their identities were renegotiated with the social context (Nolen et al., 2009). The evolution of identity as described by Nolen et al. (2009) provides a basis for examining the motivations of architectural students over their educational careers, and specifically for their propensity to use technology for design and visual representation in a discipline once built on traditional, manual methods.

Identity Formation

Holland (2010) describes the tendency of individuals to be drawn into socially and culturally created "worlds", or contexts, where specific roles are given importance and significance is attributed to distinct acts whose outcomes are given more value over others. People then derive and ascribe meaning to their own sense of self from this context and the artifacts and tools used (Holland, Lachicotte, Skinner, & Cain, 1998; Holland, 2010). As individuals engage in these social worlds, they become more attuned to relevant actions and people, and the meaning each holds within the world, evidenced through cultural artifacts (Holland et al., 1998). These sensibilities allow them to direct their own activities towards meaningful participation (Drier, 1999; Holland, 2010), and individuals can then choose whether or not to participate. When they move from one context to another, for example, from education to professional practice, the frame of reference for personal relevance will also change; social worlds may reference each other, but may not manifest the same meaning or requirements for participation (Drier, 1999; Holland, 2010). Skills needed to succeed in the educational studio are not necessarily the same ones emphasized in the professional firm. For example, individual projects are the norm for design in school, but collaborative teams are more typical in a large firm.

Within the community of practice, varying identities hold value based on the modes of participation each is afforded. In Wenger's (1998) framework, the notion of identity is not static, but instead is a constant process of becoming. Identity can be described as a trajectory, constructed in the social context over time and with alterable outcome (Wenger, 1998). An individual's identity will not only change with time, but the ongoing formation motivates toward participation in specific communities (Dreier, 1999; Harackiewicz et al., 2008; Holland, 2010; Nolen, Ward, & Horn, 2011; Nolen et al 2009; Wenger, 1998). These trajectories fall into types that describe the identity's movement in relation to the community; most pertinent to architecture are these three types: inbound, insider, and boundary (Wenger, 1998).

1. **Inbound trajectories** are concerned with the newcomers to a community. These identities are focused on their future participation. Architectural student trajectories are involved in creating and deriving meaning that will allow them to become part of professional practice.
2. **Insider trajectories** belong to fully participating members, but are not static. They include the ongoing learning and negotiation of evolving practice. Professional architects

find themselves adjusting identities throughout their careers, often moving through paths that include design, technical expertise, management, and business development (Wauters, 2012).

3. **Boundary trajectories** belong to identities that link different communities. In education, instructors bridge the boundary to the profession and link students to the necessary skills and learning required for participation in future communities. In professional practice, intern architects embody the link as graduates-in-training to become licensed architects. They are the apprentices in the community of professional practice.

For each of these trajectories, meaning in one community is linked to taking part in others (Dreier, 1999; Holland, 2010; Nolen et al 2009; Nolen et al., 2011; Wenger, 1998). Learning in one will affect others; constraints in one may result in constraints in the next (Dreier, 1999). Ability and action must be coordinated in any community in order for an individual to be accepted for membership, and abilities will be determined by the value of the cultural resources (Holland, 2010; Wenger, 1998). If student motivations are in part influenced by their identities in context, the characteristics of each identity can then promote specific goals for the individual (Harackiewicz et al., 2008).

Design students often associate meanings and values with technology even before they are introduced to using it within the design process (Dinand & Ozersay, 1999). For novice design students, learning design encompasses many different tasks and develops many abilities. Students arrive at university with computer experience, but do not have equal familiarity with the use of technology in the design process. Many design programs have preparatory class requirements to be met before the design curriculum can be attempted. It is at this time and in the context of beginning classes that design student often begin forming their identities, exploring their skills and attempting to develop their abilities in the facets of design (Campbell, 2006; Kellat, 1996). Understanding how these identities will affect student engagement with technology is essential to positioning that technology's use in design.

As students begin their studies, specific skills are not equal across all individuals. One particular skill is visualization, which can also further divide into objective and subjective modes, where the viewer chooses to either attribute or derive meaning from an image. Visualization skills are often taught through multiple manual drawing courses, where students learn the architectural conventions of perspective and orthographic projection: the two-dimensional representations of a three-dimensional space, known as plan, elevation, and section. Many may struggle with the cognitive visualization from one to the other, imagining what the three-dimensional composite of multiple two-dimensional representations should look like, and vice versa (Ataman, 1999). As a support for these types of struggles, literature has suggested that computers can function as tools for cognition, allowing novice designers to physically see the three-dimensional views of their designs much more easily than having to imagine them (Ataman, 1999; Maze, 2002), thus strengthening the development of this internal ability. However, literature also suggests that this skill may instead be diminished with overuse of computers for visualization (Angulo et al., 2001).

In the context of the formative design classroom, students begin to see the requirements of the design community in terms of their own abilities. Instructors and peers value expected skills and abilities that are essential to the definition of a "good" designer, and students begin to develop a sense of their competence within this community as their identities develop (Nolen et al., 2011). Situative theory places each student in the system of this design classroom community, and as newcomers, the desire to establish membership can motivate a desire to learn and position for a trajectory that will allow them to establish competent membership (Nolen et al., 2009). Seen from this point of view, the reasons for student interest in computer use at the beginning of the educational career is support for effort and the perception of ability in the context of learning design. At this novice level of design, students defining their positions within the culture of design education value the “curriculum opportunities that reaffirm their talents” (McCaslin, 2004, p. 271). Situative theory does not separate individuals’ participation from their community; students’ use of technology at this early stage and the methods and practices they adopt will influence and co-construct the value of technology to their current identities (Nolen & Ward, 2008; Wenger, 2000). The cultural artifacts and tools that are used in the community have histories that are developed through the relationship to the particular tasks for which they are used (Holland et al., 1998); in this case, representations and the tools used to create them — technology and software — are defined by and hold meaning for each community that uses them.

In architectural education, students renegotiate the value of knowledge and skill for their current identity (Nolen et al., 2009) among their peers in studio. As students move progressively toward entering the community of professional practice, the value they place on technological skill within design is renegotiated to align with the corresponding value placed upon it in within each specific context. Student motivations then evolve and develop on an individual level to match these new meanings in context. Meanwhile, they must contend with any conflicting values that are not shared across these communities (Nolen et al., 2011). However, if the contextual meanings are unclear or misaligned, students situate themselves on paths that may not necessarily lead to direct participation in their selected community of practice. Educational contexts are intended to prepare students for participation in future contexts, providing directives of what is considered to be valued, but the shifting nature of social worlds or communities of practice can produce problematic references (Drier, 1999).

Chapter 2.
Technology in Contemporary Architecture: Practice and Education

Technology in Professional Practice

The discipline of architecture is constantly undergoing change due to advancements in technology, creating shifting social contexts for individual perception and community practices. While this often manifests as training and experience in software programs and hardware configurations, the changes that occur within the culture of architecture are more in reaction to external pressures than to intentional adjustments to practice. The influences of technology on architecture have been numerous, and the following literature review notes adaptations in the community relevant to the current study of digital representation. These include adaptations in the social context of the architectural firm as well as ways of thinking needed to utilize the capabilities of advancing technology, all of which affect the communities of practice and consequently, the formation of individual identities. Socially, offices have seen a new team typology emerge, in which individuals with different types of expertise are paired to leverage knowledge. In addition, both the need for knowledgeable software users and internal and external office collaboration continues to increase. Cognitive changes include shifts in the use of digital representation within the design process, as well as the approaches to thinking in ideation and concept work. Reviews of these social and cognitive changes will be expanded in this chapter.

The pace and demands of architectural practice force many firms into change without much planning (Jog, 1993). This process of advancement and adaptation has caught some by surprise, and encouraged others to prepare. Since 1990, the use of computers and CAD software for preparation of construction documents has been ubiquitous. This technological adaptation was different from the one now most commonly occurring in contemporary practice, which is the evolution of the practice into digital representation, specifically into photorealistic rendering and building information modeling (BIM). Typical 2D CAD software, used in the 80's and 90's, functioned much as a new tool to replace the traditional task of preparing hand-drawn construction documents in the end phases of design. Training was required, but the essential activity of drawing two-dimensional lines to represent plans, elevations, and details had not changed too significantly. In contrast, both BIM and digital building modeling have come to simulate construction of the building in digital format, at both early and late phases of design. Small and large offices are finding the need to modify their processes to include — if not switchover completely — to BIM (Birx, 2005; Hyde, 2007; Ibrahim, 2006; Wauters, 2012). The training, preparation, and resources needed to integrate BIM use in the professional office have prompted change in more than just software; many firms have experienced necessary adaptation that has affected both the social culture of the firm and the conceptual processes that are involved in design and production.

Knowledgeable Technology Users

BIM requires a different user than previous CAD platforms (Birx, 2005). The integration of this type of technology cannot rely on operators who only manipulate software, without an inherent knowledge of building and construction. More traditional team typologies could rest on a lead designer to provide direction, with other members documenting intent with symbolic representation and a cycle of review and revision ("redlining" or "markup") until the intended design was well recorded and detailed (Birx, 2005). The newly evolved office requires more knowledgeable users in the design process, not in the documentation phase. As a result, team members can no longer function solely as drafters. BIM requires content knowledge, not just manipulation. Architects should know and understand the processes of construction in order to participate in the creation of the model. Since many of the most experienced architects may not have the expertise required in this new software, training is essential to utilize knowledge resources efficiently, unless other adaptations to the process can be made.

In order to leverage all available knowledge and content expertise, Birx (2005) and Ibrahim (2006) advocate that understanding and training should include not just those who will actively use BIM, but also managers and lead designers that will supervise and guide ongoing projects. As staffing models change to accommodate the required tasks, without training the "technology gap" between tech-proficient and tech-deficient individuals will widen (Birx, 2005; Kogan, 2009). For individuals and firms who do not or cannot prepare for ongoing change, compelling adaptation to new staffing needs is inevitable to remain productive (Kogan, 2009).

The definition of a productive individual in the professional community has changed in light of the new technology. The use of BIM and digital representation has increased in significance within the shared repertoire that now consists of tools and processes that require architects who can use them. Without the ability to use the new tools, comprehensive participation may become difficult, forcing the professional community to adapt in order to maintain the joint enterprise of design. Individuals may find themselves needing to align themselves with a learning trajectory that will allow them to form the required identity for ongoing participation in their current community. For current members in practice, this type of learning trajectory may include formal or informal training in new software or documentation processes that will allow them to participate or manage others in the practices that change due to BIM use.

The Paired Approach

One of the most significant adaptations that have occurred within the social structure of offices regarding the increasing use of BIM is the emergence of a new typology for the design team. In the traditional architectural community, a senior, more experienced architect usually leads design. Support and assistance is provided by junior, less experienced intern architects, who are understood to be still in training and learning the details of their craft. When work was done by hand, common tools were useable by all. In contemporary firms, the use of BIM and other software for realistic representation is often left to the younger, less experienced members of a team; although the more senior members possess greater content knowledge due to their years in the industry, they are often also less adept or reluctant to learn new software technology. As a result, the culture of the firm has evolved to assemble design teams that are made up of at least two members: a senior, more experienced architect, and a junior, less experienced architect with expert skills in the software technology. Rather than a team dynamic in which the senior member holds greater knowledge meaningful to design, both the senior and junior member work together. They each draw upon their respective expertise in a collaborative effort and jointly become responsible for learning and teaching. Lassor and Pocorobba (2010) advocate this method of developing knowledge as “two-way mentoring”, going so far as to recommend and develop training programs in which the mentor groups collaborate to strengthen missing skills.

Groleau et al. (2012) examined the organizational changes required in an architectural firm’s practices due to the attempted integration of technology into the existing social context. The authors identified patterns that manifested the change required when the office chose to use technology to produce renderings for proposed projects instead of using traditional hand-drawn methods, intended both to communicate ideas and to influence client approval. New collaborative processes emerged that focused on the identities of the individuals involved and how they internalized the changes to existing practices. Two areas of change are of primary interest for applicability to technology integration: the artifact of visual representation, or rendering, and the redefining of the roles within the firm.

Of primary concern to architecture as a profession is the quality of design and work (Beeftink, Van Eerde, Rutte, & Bertrand, 2012; Groleau et al., 2012). The firm's decision to move to computers for visual renderings was based on the financial need to win more contracts for work; however, the change in technology required that the principals adapt their personal valuation of hand drawings as fundamentally important to expressing the individuality and quality of the firm's work. The time to complete a computer rendering can be significantly shorter than the time required for a hand drawing; in order to remain financially competitive in the market, meaning once attributed to hand drawing was lost to digital representation.

In order to facilitate use of the new technology, the organization required staff that had the required skills to operate the software. Rather than train a current employee, an intern was hired to become the computer specialist. This decision forced a change in social roles within the firm; senior partners once tasked with creating concept and design to be then executed by junior members and drawing staff were instead required to collaborate with the intern directly in order to develop the project (Groleau et al., 2012). While direct contact between senior partners and interns is not unusual, the collaboration as a team is a new development (Birx, 2005), transforming the social structure and the traditional relationships in the firm.

Increased Collaboration

Collaboration inside the office is only a part of the influence of BIM. The introduction of BIM into the architectural design process has also enabled other disciplines to become more involved in the early stages of design. Unlike traditional CAD processes, the design is not developed and then transferred to two-dimensional documents from which contractors then bid and build, allowing many of the construction decisions and revisions to be made later in the process. Instead, in BIM, construction systems are selected and designed in conjunction with the concept of the building itself: wall systems, floor assemblies, mechanical systems, and electrical systems.

Due to the detailed nature of BIM, the construction and engineering disciplines are able to become involved earlier in the design process, to facilitate decisions that can impact cost, time, and efficiency of the completed project. The level of collaboration between the disciplines has increased. Integrated Project Delivery, or IPD, has become more prevalent as a project process in which all collaborators, or stakeholders — client, architect, contractor, consultants — cooperate in design and construction for project performance and success (Getov, 2010; Wauters, 2012). An understanding of the leadership roles that architects now play when BIM integrates collaboration in phases of a project is vital to effective participation where others become contributors in the design (Getov, 2010; Kalay, 2009). Rather than a linear process of design from one stakeholder to the next, the architecture, engineering, and construction (AEC) trades share information in BIM integration, necessitating a shift to project workflows over individual processes and forcing change in previously siloed professions (Ashcraft, 2010; Kalay, 2009).

As development of design becomes increasingly virtual and global, sharing of the model becomes complex and fluid (Marion, Fixon, & Meyer, 2012; Rubel, 2013). BIM data can be extracted for other analysis, allowing closer relationships for design but also exposing difficulties in communication between individual disciplines (Ibrahim, 2006; Rubel, 2013). More and more individuals and interests are invested in the design, and architects are relied upon for progress visualizations of the finished building in conjunction with other analysis for decision-making.

While literature addresses the change in thinking that must occur due to the accepted use of technology in architecture, clear direction for the productive and thoughtful integration is only just emerging. Many of the observations most pertinent to the changes occurring in cognitive process are reflective; experienced practitioners look back on the traditional ways that design concept, schematic, and development proceeded, and compare those to many of the processes that now often involve and depend upon technology. Perspectives of these changes are both positive and negative.

Problem Analysis and Innovative Design

The design process has often been described as reflective, where the designer visits and revisits work and ideas in order to find a solution that best fits the problem (Schon, 1983). Unique to this process is the idea of “puzzle-making” (Archea, 1983) where both the design problem and solution are adjusted in related ways to find the most satisfactory condition. For many, this process may not necessarily be linear, but instead involves return to previous ideas that can prompt leaps to new ones. With the use of technology and the current advancements in digital representation, designers are now able to externally visualize forms and construction that otherwise may not have been achievable (Abdelhameed, 2004; Lim, 2004; Oxman, 2006).

Traditional forms and spaces do not need to be the starting point. Instead, representation and experimentation for problem analysis can be explored, with the ability to “undo” and “redo” as needed. New design approaches in parametric digital modeling can focus on geometric relationships in responses to variables that explore specific design requirements or opportunities (Menges, 2010). The affordances of the software design tools can become the impetus for the design iterations and for solutions (Lim, 2004; Oxman, 2006), changing both the process and the outcome. Instead of design conceived and drawn, it is calculated and then generated (Kolarevic, 2010). The traditional cognitive process has changed; conceptual thinking is not necessarily confined to the mind of the architect, but can now be assisted and inspired by the representation of the digital model (Menges, 2010).

Research by Chen (2001) describes how the design process is assisted by digital representation during problem analysis. Thinking and design can be done in a process that deviates from traditional methods, specifically during the early conceptual phases of a project (Chen, 2001; Abdelhameed, 2004). Analysis of the impact of decisions on building efficiency, cost, time, etc. can be explored in order to provide information that will allow earlier design changes (Birx, 2005; Hyde, 2007; Ibrahim, 2006; Scheer, 2011).

The Importance of Abstraction

In contrast to those thrilled by the innovation that digital representation affords, some concerns have surfaced; of greatest concern is the increasing tendency to allow the affordances of digital representation to take precedence over traditional ideation methods in terms of time efficiency. A significant constraint of BIM and many modeling applications is the loss of abstraction and ambiguity in beginning a design concept through ideation. Issues of detail and preciseness that may not yet need to be made for conceptual purposes and problem exploration must often be made in order to effectively use software (Kalay, 2009). In contrast, representation in the two-dimensional sense has often been used to the designer's desired effect, exploiting abstraction of form or information to emphasize specific details and diminish others (Scheer, 2011). Sketching has long been appreciated for an ease of design exploration that digital tools have not yet superseded (Seebohm, 2007), facilitating the ambiguity that is often desired in early ideation (Prats & Garner, 2006).

Materiality in Design

These affordances provided by the tools of digital representation lead inevitably to change within architectural practice. As designers utilize new and improved tools, they allow the technology to influence both individual and company processes (Groleau et al., 2012; Kalay, 2009; Lim, 2004; Scheer, 2011). The materiality of construction methods has become essential to the process of using digital representation to visualize the building (Hyde, 2007; Ibrahim, 2006; Scheer, 2011). In the construction of the virtual model, data regarding material properties, quantities required, spatial relationships, light analysis, etc. is simultaneously created in a database, supplying access to information beyond the standard visual representation. The required parameters of a final design can be used to control the process and outcome of the model, providing a more practical representation of the expected structure in terms of time and cost.

Architecture has long been a practice that emphasizes materiality in design, where engagement with the material is essential to the design process (Kolarevic, 2010). With BIM as a digital representation of a physical building, the design must now include not just the idea of construction, but also the actual details that correspond to construction (Ashcraft, 2010), in order for the information to be accurate for those who will use it.

Technology in Education

The growing trend toward use of digital fabrication in architecture spans the communities of professional and educational practices, likely due to the shared understandings of significance in innovation it brings to the craft (Greeno, 2006). While digital representation manifests influence in professional practice, it has also influenced education and the preparation of students. The two communities are not identical, but desired competencies in technology have favored change in both. Changes to the community of education in recent years are also perceived to be both positive and negative. Prominent social changes include an evolution in student expectations, student tool selection in the studio, and changes to the traditional studio dynamic. Changes that indicate possible shifts in thinking are improved representation and tools, the tendency to become involved in detail early in the design process, ideas influenced by software, and emphasis on solution analysis.

Expectations for practice

Design studios are often focused on providing students with specific opportunities to learn and practice skills that are expected in professional firms (Lawson, 2009). As professional practice has integrated technology into the design process, students increasingly expect to learn and use technology — specifically digital representation — in ways that will help prepare them for work as architects (Dinand & Ozersay, 1999; Markus & Kitayama, 2010; Pektas & Erkip, 2006). Their perceptions of technology are influenced by what they observe and experience of the professional world while in school, from visiting practitioners, guest lecturers, and instructors. The real projects completed by professional firms influence students to seek ways in which they can learn to do similar work (Chiu, 2003; Klinger, 2009), encouraging them to seek ways that their educational participation can find parallels. The prevalence of digital tool use in the profession leads instructors to structure courses in the belief that they can facilitate new possibilities in design inspiring students to explore new directions and processes like generation, mutation, animation, and performance-based (Chiu, 2003; Diniz, 2012; Klinger, 2009). When forming trajectories for the future, students assume that their community can match the professional community by readying them for future membership, and seek for ways that they can align themselves.

Tool Use in the Studio

For many educators, the possibilities for design afforded by advanced digital representation is where technology can change pedagogy, specifically design process. Students can use digital representation to aid thinking, and stimulate cognitive process earlier when facilitated properly with curriculum that builds skills using technology as the tool (Ataman, 1999). Rather than being required to practice numerous cycles of representing 2D spaces in 3D and vice versa through orthographic projections and perspective drawings, students can produce a digital model and utilize it to reveal those drawings and to experience changing spatial perspective (Ataman, 1999). Digital representation can be used to visualize design possibilities through animation of form; iterations of a virtual model can give inspiration for concept possibilities (Chiu, 2003, Diniz, 2012). The designer may no longer need to imagine solutions, but can experiment with a model of abstract forms created by algorithmic input. Designers can be inspired by the forms the model reveals, since many of these forms could not be explained on paper with traditional two-dimensional representation (Oxman, 2006). This can influence new design methods, and in turn create new pedagogy that challenges the logic of current design thinking (Oxman, 2006). Proposed curriculums include learning and manipulation of software in early undergraduate education to introduce students to the use of multiple medias in studio and the design process (Diniz, 2012; Duarte, 2007).

The possibilities that digital representation promises both for efficiency and ease of visualization have changed the means of expression in the studio. As a consequence, traditional skills of drawing on paper are observed to diminish as students turn to CAD for representation and documentation of ideas (Angulo, et al., 2001). Ideas also appear to be less important, as students focus more on the technology and its use (Barrow, 2006). Digital representation as a tool in the joint enterprise of design has begun to influence the meaning of design made in the studio, where tools are part of the shared repertoire.

The Studio Dynamic

These changes, in turn, have shifted the social dynamic of the studio environment. Rather than the traditional surroundings of tables, sketches, and other accouterments of visible creativity and process, the physical space has changed to accommodate computers (Binder et al., 2011). In a study by Ivarsson (2010), students were observed centering their discussions around the computer monitor, manipulating the virtual model to see what it could reveal about the design. The were not observed communicating ideas to each other with pen and paper, but instead waited intently for the computer to reveal the design, and made suggestions to each other concerning the commands to use next to move the process along. Rather than looking to an instructor to facilitate, students may choose to "learn" from the output of the computer, as "more knowledgeable" as described in sociocultural learning theory (John-Steiner & Mahn, 1996; Lave, 1996; Omrod, 2008; Tharp & Gallimore, 1988; Vygotsky, 1978; Wertz, 1988). In addition, the student-centric environment of the computer screen tends to be more motivating than external teacher instruction (Hancock, Bray & Nelson, 2002). When students establish and enforce their own rules, with teachers then performing as critics, students respond more favorably and engage in more exchange of ideas (Hancock, Bray, & Nelson, 2002).

The design thinking that once would have been exhibited on numerous pieces of paper or sketch models for review decreases in physical form, replaced by a digital model in only one state of completion. Students must then express their steps in the design process verbally, rather than showing physical diagrams or process sketches. Project critiques, if students only show work on the computer, lose the real-time comments and alterations procedure that was once done on paper (Schon, 1983). Novakova (2011) describes a study where the medium for drawn comments and suggestions was lost due to computer use, and the instructor was not always able to demonstrate to the students what or how changes could be made. Rather than being able to show a student suggestions for revisions, instructors were only able to provide verbal commentary to be acted upon at a later time (Novakova, 2011). With digital visualization, both presentations and discussions of student projects are influenced by the medium of the presentation. Students choose perspective viewpoints and representations of thinking for demonstration of ideas, rather than having physical models that allow viewers to experience their own perceptions (Lyner, Ivarsson, & Lindwall, 2009). In an effort to bring traditional and digital tools together to solve related issues, developments in education seek to combine both in innovative ways, such as tangible user interfaces that integrate digital visualization with physical tools (Hsiao & Johnson, 2011).

Improved Representation and Analysis

For those who have been able to incorporate technology into architectural curriculum in a mindful way, the immediate benefits of digital representation have been numerous. When used early in education, students are able to utilize the affordances of technology for improved visualization of design and ideas, not unlike innovations used in professional practice. For some, it promises to assist cognitive development by freeing designers from laborious repetitive processes to facilitate higher order thinking (Ataman, 1999). Students are more quickly able to move on to improved design revisions once the computer shows them the results of their design decisions. Early introduction builds technical expertise in software that can then be used in future studios, assisting the design process and analysis of solutions (Ivarsson, 2010; Rugemer & Serrato-Combe, 2008). The use of digital media has been shown to contribute positively to knowledge building and retrieval in design (Abdelhameed, 2004). Drawing digitally rather than by hand has also been shown to favor individuals with visual cognitive styles (Pektas, 2009), further facilitating visualization for designers.

The changes to design thinking in education have also been expanded with the use of digital tools. As students experiment with software and parametric design tools, they, like their professional counterparts are exposed to new forms not previously considered (Lim, 2004; Oxman, 2005). Rather than defaulting to existing historical typologies and ideas, they can explore generative designs for inspiration and ideation, and manipulate digital models in ways that could not be completed in physical or sketched form.

Technology integration with physical form has also been a successful area of innovation in architecture curricula. Laser cutters, CNC routers, 3-D printers, and other computer-controlled devices allow students to experiment with digital models and then fabricate them to facilitate learning about the processes needed to create physical objects from virtual representations (Carraher, 2011; Ruegemer & Serrato-Combe, 2008). Digital processes built on the foundations of physical tools can also facilitate design thinking (Hsiao & Johnson, 2011), allowing individuals to make connections to the use of both tools in the design process.

While the use of digital representation continues to evolve in education, its prevalence over the years has led to observations on the negative effects that have manifested in student work. Clearly, students choose to employ tools that they believe will assist the design process. Equally clearly, the tools affect both the intention and the outcome of student work. The concerns of their instructors focus on the ways that students have chosen to utilize the tools in their processes. These are described below.

Level of Detail

The tendency to focus first on modeling specific details rather than the traditional approach of abstract ideas and concept has been seen as an issue when integrating technology use in the educational studio (Ambrose, 2010). Students often choose to focus on detailed work during the concept phase of the design process, rather than staying at an abstract level (Chen, 2001). Considerations such as exact dimensions, material, or placement interrupt the design process, and derail the exploration of possible solutions. Students have been observed focusing on one design and creating similar iterations rather than experimenting with new directions. As a result, students who begin working entirely with digital means may choose not to consider alternatives (Dow et al., 2010; Novakova, 2011). At a time in students' education when agility in tool use and ability to express and explore ideas is most important, the use of digital representation in the design process may actually prevent students from being able to do so.

Hindering Creativity

In addition to the concerns regarding loss of abstraction during early concept work, studies have shown that students also allow the constraints of digital representation to hinder their creative process. Akin (1989) described the false sense of ability engendered by mastery of the software. This can deceive students in to believing that they are experienced designers with well-developed ideas; their skillful form manipulation creates designs that appear to be complete. Novice users have been observed to be unable to visualize a space without consulting numerous views of a digital model (Chen, 2001). The concern that students favor software biases of affordances and constraints coupled with increasing arbitrary design decisions that appear to be driven by the computer and its visualizations raise questions about the negative influences that technology use may have (Balfour, 2001). Kendir and Shcork (2009) observed:

> Over the past few years we have recognised that students increasingly make their designs software-dependent. Rather than developing a strong design idea and finding or creating an appropriate tool for its articulation, they tend to use readily available software tools…This uncritical use of software often confuses style with design, resulting in a homogenised architectural repertoire where expert use of techniques displaces well articulated design ideas (p.749).

Rather than questioning design decisions and developing thought processes that critically analyze ideas, students manipulate a digital model with software tools to create images where photorealism may hide mediocre design. Students can be led by the software to believe that they have developed an idea, when they are instead exhibiting mastery of the tool.

Solution Analysis

Students' inclination to focus on the affordances of digital representation reveals another trend in technology use. While professionals may utilize digital representation early in the design process to visualize ideas that best meet project requirements during concept development, students have been found to select a specific solution and pursue it using virtual modeling of that solution, with the intent of viewing the idea to analyze its validity (Chen, 2001; Ivarsson, 2010). In a study by Ivarsson (2010), students were seen to use a digital model to understand what they had designed, and how to best create a building section. By manipulating a cutting plane back and forth across the model, they could "see" what the outcome would be. Instead of imagining what the section cut should look like based in their ideas, they used real-time representation to examine and compare their choices. Chen's (2009) observations showed that, unlike expert designers, novice designers tended to use the computer to conduct visual evaluations after the design concept had already been developed, rather than during their exploration of the concept (Sachse & Hacker, 2011).

Changes in Pedagogy

Students in architecture often find themselves entering a world where a number of different skills and abilities are expected of them as they attempt to learn the norms of a long established discipline. The environment of architectural education is concerned with preparing students for working in professional practice, yet students must wrestle with the position of novice and learner until they are able to prove competence within the culture of design, which has many meanings, defined both from within the university and also by the influence that professional practice exerts on educational preparation.

In recent years, preparation for computer use in design has become one area in architectural education heavily influenced by professional practice (Ataman, 1999; Chiu, 2006; Coyne, 1996). As CAD has become more and more prevalent, offices have demanded that graduates learn CAD skills in their preparatory degree (Andia, 2001; Jog, 1993). As the use of technology for design evolves in the profession, so have the skills required from graduates, from simple CAD tools to integrated building design (Birx, 2005), and architectural education has made many attempts to integrate these within the curriculum (Balfour, 2001; Chiu, 2006). Most architectural curricula are already intensive and time-consuming, requiring two or three years beyond an undergraduate degree to achieve the terminal degree required for licensure. Incorporating additional classes into the Master of Architecture program to teach the technical skills desired by the profession is not simple or straightforward. In addition to the complexity of program planning, keeping up with the changes in preferred software is difficult. The advances in technological ability for design visualization over the years have evolved dramatically from computer aided drafting to virtual models and realistic representation of buildings and environments. Development of faculty and curriculum that can match these advances is a constantly evolving exercise. As mentioned previously, even the professional discipline has had difficulty determining the processes for integration of technology into the design process (Andia, 2002; Birx, 2005; Jog, 1993; Kellat, 1996).

The motives behind attempts to integrate technology into architectural education are often as numerous as the attempts themselves (Akin, 1989; Andia, 2002; Asanowicz, 2007; Balfour, 2001; Chiu, 2006), and evidence varying levels of success, typically dependent on the proposed outcome. Methods have ranged from integration of digital technologies at the start of the program to classes at the end; stand-alone software instruction classes and design classes that require the use of software; and elective classes in technology, rather than degree requirements (Asanowicz, 2007; Carraher, 2011; Reugemer & Serrato Combe, 2008). Each approach presents unique challenges to pedagogy, resources, and traditional design thinking, but literature reveals few that incorporate or address explicit learning theory into the process. In addition, very few studies consider the importance of the student perspective, focusing instead on output and artifacts created by students.

In contrast to the many concerns described above, other studies indicate that when students do take opportunities to integrate technology in their design processes and do not allow it to hinder creativity but use it to develop concepts and ideas, outcomes are different, and often show improvements in design, thinking, and execution (Carraher, 2011; Ruegemer & Serrato-Combe, 2008). Student work provides insight into the competencies that students have or have not exhibited in courses. These artifacts, however, cannot by nature reveal the internal motivations of individuals or the sociocultural influence of the studio environment and professional practice on personal perceptions. Why do students choose to learn one skill over another, despite the intentions of their instructors, and how does this affect their entrance into the professional community? This study attempts to uncover reasons for these complex motivations and the resulting effect on graduate success.

Chapter 3.
Methods

This study was qualitative in nature, leveraging as a major resource the personal observations of practicing licensed architects in the professional community. While personal observation and experience may only document the perceptions of a single individual, aggregate observations and data often reveal trends in a specific area of study. The architectural discipline may be made up of multiple communities and sub-communities, but many of the mutual shared understandings about the practice and its joint enterprise should unify perceptions on specific subjects. I selected this approach since my background in the discipline would allow me to interpret narratives in a holistic manner.

Setting and Participants

Interviews with fourteen professional practitioners were scheduled and held primarily at the offices of architectural firms in the Pacific Northwest. The primary interviewee determined location, time, and additional participants at any given interview. Total respondents in the interviews were twenty-one practicing professionals. Interviews were held during and after working hours, in private conference rooms and within earshot of other employees and people.

Interviewees were selected on the basis of their interest in architectural education and direct prior involvement with intern architects entering practice at the entry and novice level. Involvement included participation in student critiques, advisory participation, new hire review, and staff management and mentoring. Each interviewee also had experience in learning and using both traditional tools and digital tools for design and representation, including AutoCAD, SketchUp, Revit, Rhino, and the Adobe Creative Suite. Skill sets in software were varied, as were the personal use and the office use. Years in practice, firm size, formal office training in digital technology, and process phases that utilized digital technology were also recorded.

Classroom observations were conducted in an undergraduate course in the architecture department of a university in the Pacific Northwest for the duration of a school quarter of ten weeks. This introductory computer class was taught with a curriculum that differed from previous years; the fundamental focus was the connection of digital design software use to physical fabrication. Twenty-eight students enrolled in the class were observed, as well as the instructor and a teaching assistant. Since the course was an elective to other programs in the college a small percentage of students were from the construction management and landscape architecture programs. The course was a lecture-based class that ran concurrently with core design studios in which architecture students were also enrolled.

Data Collection Strategies and Procedures

During the data collection period, a total of 533 pieces of data and artifacts were collected. Data included interviews, observations, with each item counted once (i.e. each interview was one piece of data, each observation session was one piece of data). 111 pieces of data were used in the analysis. Interview transcripts, observation transcripts, and surveys were selected based on relevance to the research questions. Progress and final artifacts that demonstrated competency in the class objectives were selected from the case study. The data sources included one-on-one semi-structured interviews with professional practitioners, classroom observations, final review observations, student surveys, student work samples, and course curriculum (see Table 3.1).

Table 3.1. *Study Design*

Data Sources	N	Interviews	Observations	Surveys	Artifacts
Professional Architects	14	Semi-structured	N/A	N/A	Sketches, Drawings, Renderings, Physical Models, Digital Models
Instructors	1	Semi-structured	8	N/A	Syllabus, Lesson Plan, Assignments, Assessments
Students	28	N/A	8	3	Digital Models, Renderings, Physical Models

Interviews. I conducted one-on-one, semi-structured interviews with licensed architects practicing professionally (See Appendix A). Each interview lasted from forty-five minutes to two hours. At each interview, interviewees were asked about general observations of technology use over recent years, and the influence that digital representation has had on firm practice, including design and documentation processes. Participants tended to provide narratives about their experiences. Interviews were structured to focus on issues selected by each respondent as an indication of the topics that had most influenced the office practice and structure. Hand written and typed notes and audio recordings were taken at interviews for transcription and analysis at a later date (see Supplemental Materials).

Classroom Observations. The classroom observations were conducted during the scheduled class hours only. Seven class period observations of four hours each and one final critique of three hours were included. During the observations, I typed transcripts of dialogue and events on my computer as they occurred. These transcripts were then combined with personal observation for analysis through coding (see Supplemental Materials).

I was not introduced to the students in any formal way, but students were informed that the instructor was considering the course progress and outcome for use in a graduate thesis and asked for consent. Since I began attending the class from the first meeting, students did not seem to show interest in my presence, assuming that I was there for the instructor's benefit. After the first meeting, I sat in the back of the classroom so I had a clear view of most of the students, the instructor, and the front of the room. None of the students asked me any questions, even during class critiques.

Surveys. During the classroom observations, three surveys were administered to the enrolled students: Introductory survey (see Appendix B), Progress survey (see Appendix C), and Last Day survey (see Appendix D). Surveys consisted of multiple choice and short answers. Survey questions for the Introductory survey and Last Day survey were designed by the instructor to discover initial student skills and final student competencies in the software, Rhino. Progress survey questions were designed by me to indicate overall student motivation for technology use.

Artifacts. Student artifacts were collected at each assignment submission point. . Final projects included student presentations and physical models. The instructor selected specific artifacts as examples of satisfactory and exceptional student progress and learning in both the software taught and fabrication through digital and physical models.

Data Analysis. Initial analysis began with review of transcripts and notes to determine emergent themes in the data collection. Data sources were matched with research questions (See Table 3.2). The qualitative approach permits the progressive development of categories and theories as research is reviewed (Tracy, 2013). Grounded theory provides a basis for this analysis, where emerging themes form the basis for emphasis (Charmaz, 2006; Glazer & Strauss, 1967). In addition, iterative analysis (Tracy, 2013) was used to move from top-level concepts to deeper and more meaningful interpretive themes.

Data was reviewed and analyzed in progressive cycles, prompting complex connections between the data and sociocultural theory. The data collected from professionals and from students was analyzed separately and then in tandem in several cycles, so that each analysis could inform the next.

Table 3.2. *Research Questions and Study Design*

Research Question	Source(s) of Data	Analysis
How have advances in digital representation since1990 changed professional architectural practice and education?	Professional Interviews Artifacts	Creation of a code list. Open coding. Themes were examined across interview data.
Does the use of digital representation influence the skills most valued in these two communities? If so, how?	Professional Interviews Student Surveys	Creation of a code list. Open coding. Themes were examined across interview data.
What effect does digital technology use have on perceptions of student capabilities as they enter the profession?	Professional Interviews Student Surveys	Creation of a code list. Open coding. Themes were examined across interview data. Survey results. Self reported data from student surveys.
How can contemporary education better integrate digital representation to prepare students for professional practice?	Professional Interviews Student Surveys Observations Artifacts	Creation of a code list. Open coding. Themes were examined across interview data. Survey results. Self reported data from student surveys.

Coding and Reliability. Code development also emerged during analysis, focusing first on activity in the communities, and then on the meaning that could be derived from the practices in relation to the discipline and nature of the architectural process. I determined preliminary first and second level codes, which were then reviewed by the thesis committee members for coherence to architecture and learning theory. Specific applications of codes were also reviewed for consistency of interpretation with both definitions and examples (see Appendix E). Data excerpts were identified and marked as specific activities that correlated to the developed codes.

Further Analysis and Data Selection. Data was coded using the web-based application Dedoose. Professional interviews and case study data were coded separately, and then compared for areas of agreement and difference. The preliminary codes determined during development were refined into primary analytical codes. Reports were generated to reveal the highest code applications and reviewed for significance to the research (see Figure 3.1and Figure 3.2).

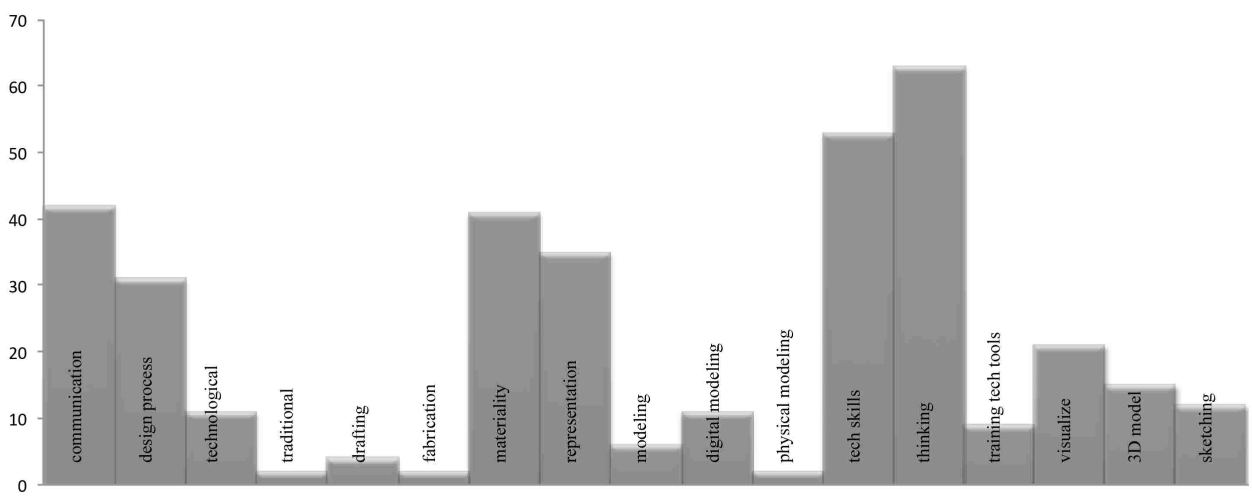

Figure 3.1. *Primary code applications*

Primary codes were defined and applied to identify actions and activities described by interviewees in terms of architectural practices (see Appendix E). Analytical codes were then determined to define the implications of the primary codes to the research questions (see Appendix E). Data that most significantly contributed to the selected themes that emerged in answer to the research questions was included in the analysis. These themes will be dicussed in more detail in the following chapter.

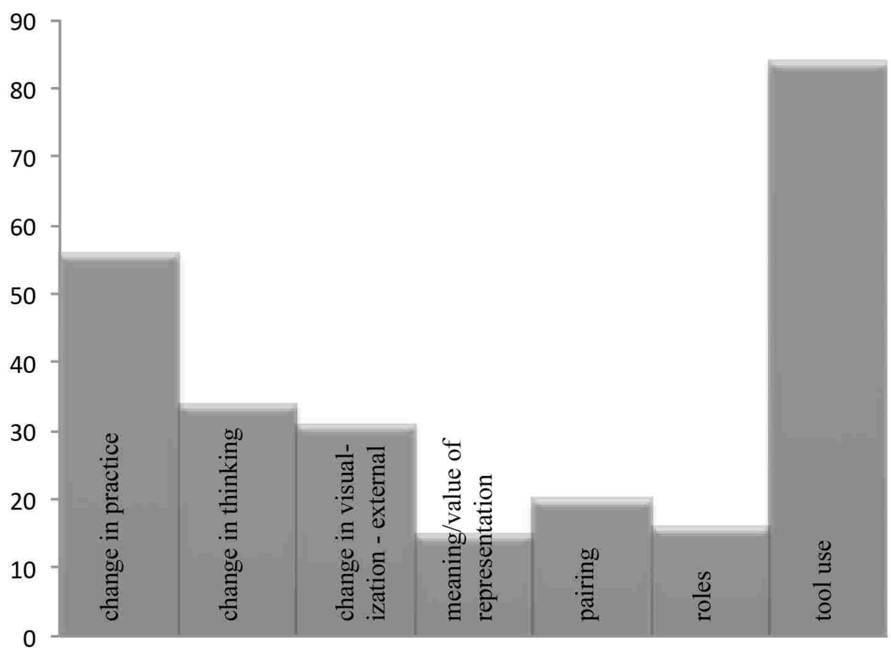

Figure 3.2. *Analytic code applications*

Chapter 4.
Perceptions of Architectural Identity

Since the major aim of this study was to uncover how digital representation influences professional practice and how this then influences student preparation, the findings presented in this chapter focus first on the interviews and second on the observations. The classroom observations provide insight into student motivations early in architectural education, when individuals are most apt to be forming identities; they also reveal the outcomes of a specific approach to integrating digital technology. Implications of the findings in light of situative theory follow in the next chapter.

During coding and analysis, three related themes emerged:

1. The skills most valued in professional practice and perceptions of how these were not evident in recent graduates,
2. The skills desired by the architecture students, and observations that practitioners have made regarding these skills, and
3. The areas of misalignment between the skills valued by each community.

Each of these themes exhibits correlations to the negotiation of meaning within the community and levels of participation available to individual identities as discussed earlier.

In interviews held with professional practitioners, although the use of technology was the main topic, specific themes regarding the most valued skills in the practice emerged. These skills were coded independently of technology skills, and for the purpose of this study, were considered to be foundation skills learned as part of a traditional architecture curriculum, both historical and contemporary. Independent of firm size and market concentration, a consistent emphasis on certain abilities was evident. The expectations placed on an individual architect were similar among all firms, and these requirements were then related to what firms sought in a student graduate and intern architect. The interviews revealed that successful membership in the different communities of architecture is dependent on the formation of an identity with the required skills and abilities, as defined by the community: “You arrive with skills, you can do certain things, but you can’t do other things. You start where you are and you develop the skills that you need” (3052 interview, 03/05/13). No individual enters a community with the exact skills that are required, but as described by the interviewee, each person develops the skills that the community values. These skills have evolved over time due to technology use and the increasing prevalence of digital representation, altering perceptions of the skills most valued in each of the two communities. Perceived dissimilarities between professional and student identities comprise the greatest opportunity for alignment through improved teaching practices.

Valued Skills

Problem Solving. Architecture as a discipline is considered by professionals to be about problem solving. The importance of problem solving surfaced in most interviews in reference to the design process. An understanding of the design process necessary for the development of an architectural solution was often the professional requirement most discussed by architects and the ability expressly desired by practice from students. Descriptions of the basic foundation skill set necessary for problem solving in the design process emerged in different terms, but was consistently emphasized. In the primary coding process, codes of “problem solving,” “idea,” “creativity,” and “analyze” were merged into the single code of “thinking” (see Figure 3.1). This code was applied a total of sixty-three times, outweighing all other codes, with only “tech skills “ in close number. The frequency of the code “tech skills” was likely due to the topic of the interviews. Creativity in thinking and well-developed understanding of the design process continue to be more important to professionals than high technology proficiency, as described by one respondent: "What your [added value] as an architect is in the ideas" (3051 interview, 03/05/13). The comment articulates one of the most important learnings for students: architects are the originators of ideas and design solutions, applying knowledge and experience. Rather than allowing expertise in digital representation to imply good design, architects start with ideas, then communicate them visually:

> …somebody has to have the idea first…after that comes, then the technology can say okay, well, here's what that looks like. But sort of the early parts of getting to that, is sort of fundamental design training (2261 interview, 02/26/13).

Fundamental design training is not necessarily the same as the use of technology or digital representation. It is knowledge and understanding of the design process, and the ability to communicate it well: "What are the best things to do? Understand the design process, work on your communication skills" (3012 interview, 03/01/13). Not only was good design training considered to be how students should prepare, but what some studios are specifically seeking also emerged: "[We're] looking for people to solve the problem, a design sense" (3151 interview, 03/15/13). Then, once design thinking has been learned, other skills can follow in learning. "I mean, you can train people to use technology. You can't necessarily teach people to think once they're done [with school]" (3012 interview, 03/01/13).

Interviewees emphasized that the ability to think about design problems for ideation is an especially important attribute to consider when hiring newcomers (students) as well as established practitioners (professionals). While the roles that either of these two types of employees could take on will differ, the required skill does not change; only the level of participation varies, based on additional skills and expertise in the process. Since architectural education is understood to build and support much of the knowledge in design thinking, a logical trajectory for future membership in professional practice begins in school. In relation to the importance of skills in technology and digital representation, one respondent explicitly stated that technological skill could be learned later, but thinking should come first (3012 interview, 03/01/13). This same attitude appears in the comment above about "idea first" (2261 interview, 02/26/13); technology use is an additional component. Students and professionals with identities that include fundamental design process skills will likely gain entrance into the community, although other skills are also sought.

Communication. The most important foundation skill after creative "thinking" in code frequency in the results (exclusive of "tech skills") was the code of "collaboration", specifically the ability to communicate with others in various settings, and was coded forty-three times in the interviewees. Whether in discussion of expected skills in graduates or in relation to technology use, respondents stressed communication for collaboration, as exemplified in the following quote:

> Communication is key. You know, we tend to work on big, complicated projects, but regardless, because we're a very team based, collaborative firm, whether it's the client, whether it's with consultants, whether it's inside the firm, being able to communicate is one of the most important skills, that anyone can have (3012 interview, 03/01/13).

Communication takes forms both outside the office with clients, and inside the office with team members and peers. Without it, the design process may not be able to move smoothly.

> Collaboration, that these two people that work together, a guy that sketches and a guy that does the virtual, if they sort of don't allow each other the voice to do whatever is brewing inside of them, the whole sort of party goes to pot there (2261 interview, 02/26/13).

The theme of collaboration is not new, but the value of the skill has changed with the use of BIM and digital representation. BIM's use in the building and construction industry has not only fostered increased collaboration within the architectural firm among team members, but also with outside consultants in engineering and fabrication disciplines. Inside the office, the emergence of the paired typology, the "two-way mentoring" (Lassor & Pocorobba, 2010), requires strong collaboration between junior and senior members to function in creative and efficient ways. Participation in the professional community — especially with the tool of digital representation — necessitates identities that value working together. As BIM continues to influence the collaborative interactions among all contributors in the design and construction process, a non-linear process of communication in integrated delivery will continue to develop identities in professional practice that can participate in all roles. Reifications of digital representation (the model) hold different meaning for each contributor (architect, engineer, builder) in the process, and individuals (technology savvy users) facilitate what is needed to communicate the meanings between the different digital representations of each discipline. Not every consultant wants the same information in the model.

Materiality of building construction. The interviews continued to reveal the complicated relationship that digital representation now has within architectural foundations skills. Interview excerpts regarding the analytical code of "materiality" were noted forty-one times. According to interviewees, observations indicate that the growing use of BIM in offices has changed the value of the skill set comprised of software ability and content knowledge. Proficiency in software use is still a desired skill, but its value is dependent on the accompanying content knowledge. An understanding of building construction is essential to its use, as mentioned by more than one interviewee:

> I would love people coming out knowing that clear concise communication is essential to convey the sense of your design, first and then second, helps if you know how to build it right. That's all they really need to know (3052 interview, 03/05/13).

Construction knowledge is essential to Revit specifically, as described below by one interviewee, "People who use Revit here are pretty good at it. But it's not the kind of program you can sketch in, it’s a pretty definitive, you have to know how it all comes together” (3011 interview, 03/01/13), and in the creation of a model in the design process as stated by two others: “You have to have an understanding of construction to use Revit” (3152 interview, 03/15/13), and “You know it kind of requires that knowledge of construction to develop a model” (3053 interview, 03/05/13).

Participation in the design process, a joint enterprise that eventually leads to a physical built object, is a highly valued practice in architecture. The growing use of digital representation during the design process with BIM necessitates the involvement of design team members skilled in the development of construction details and materiality of buildings as well as design members well versed in the use of digital representation technology. Whereas once the design team members could draft two-dimensional documents from lead designers’ intent sketches, team members who manipulate the digital model must now be thoroughly familiar with how buildings go together. In the interviews, the concern that untrained users might compromise a digital model was evident: “They are in the same model that is the final project, as opposed to just doing a detail. There is nervousness… about having junior people open up the model and do this redline” (2261 interview, 02/26/13). This nervousness suggests that identities whose trajectories have not included knowledge building in construction are less likely to be contributing participants in the design process. Skill only in the process of digital representation does not guarantee participation in design. Students as newcomers are assumed not to have expert knowledge, but will need to learn more about their craft through experience.

The application of the more traditional skills of problem solving, communication, and materiality in design are complicated by contemporary architecture’s use of digital representation. While the use of BIM and 3D modeling are not traditional skills, the identity of an architect has come to include their use when participating in the professional community.

Tool use. The relationship between content knowledge and digital representation becomes more complex when it is located within the design process. Architects in professional practice see that each step of the process requires different ways of thinking; during concept generation and problem analysis, many prefer to maintain abstract levels of visualization (Beeftink, 2012; Kalay, 2009; Scheer, 2011). Specifics of construction and material may not be desired or known, and only ideas in form or massing may be desired. BIM and 3D modeling often do not allow this abstraction.

> We're trying to use it in the design phase, because it has three dimensional visualization capability, and has the dimensional control and all this stuff, which you do need for different phases of design, it's pretty cumbersome when you don't need that. Early on, when it's an idea about how people are going to sit around a table, BIM's not helping you out too much there (3052 interview, 03/05/13).

In the early process phases described above, specificity is not necessarily needed and can be a hindrance, as also stated by another interviewee:

> Unless you're really, really mentally able to dumb Revit down in our brain and not prompt you for so much minutia early on, you have to be willing not to fall into that trap — let me just draw a line for now. But I think it's also people, it's harder to study a bunch of alternatives when you're entering a bunch of data in the box (3051 interview, 03/05/13).

Nearly all interviewees were professional architects whose early careers did not include digital technology in the form of CAD in the ideation phase. They expressed value for the simplicity of pen and paper for form exploration and study of alternatives and appreciated the unencumbered ability to quickly express and capture ideas, without the need for thorough detailing or construction methods. The tendency of digital representation to require additional decision making in order to capture an idea removed it as a preferred tool in the early phases of process for most, since its perceived affordances did not outweigh the perceived constraints. Interviewees stated that for initial concept work, BIM did not seem an appropriate tool.

In a similar way, while skill in digital representation is needed, an understanding of the importance of using it appropriately and at the proper time in the design process has become the more valued skill. The analytic code of "tool use" appeared in eighty-four excerpts from interviews. Interviewees noted many different instances in which tool use affected the design process in their offices. Efficiency in time and effort are often essential in a project, and the affordances of digital representation invite users to overlook the constraints, as described below:

> Interviewee: I think, there's… a really good example is, we recently had an early design concept, that we, in the old days would've just done hand drawings very quick kinda just to get the feel for what would fit on the site, and um, in today's technology we typically use SketchUp. Which is very loose, and, and you can go pretty quickly and get some data from it. And the team made a decision sort of separately to use Revit, which is a more robust system, but less kind of loose and facile. So they used that, and it was a disaster. Because they were getting so specific so quickly, and their whole idea was well, we'll have a really good database here, that then when we change things, it'll be if we add units, or delete them it will all just kinda automatically update. But, in that expediency they lost sight of what we were really doing, which is trying to come up with a really cool idea.
> Researcher: Start at the beginning.
> I: Yeah. And I had a, you know, pretty direct conversation with the team, about why are we using Revit versus SketchUp, and they, they came around, they realized that wasn't the appropriate technology to use, for that (3011 interview, 03/01/13).

Appropriate use of digital representation may be the most influential on the value of external visualization in the design process, and in the results ranked the highest in code occurrences. For many firms, digital representation has become a significant part of the design process beyond simple visualization of what the completed project will look like. As a tool for designer, builder, and client, digital representation has become important for its ability to provide information that will allow better decisions earlier in the design process. Analysis and understanding of ideas by clients can be a primary driver of the value of digital representation.

> …We're modeling a district in […] right now, but, in the past we would have been in SketchUp, we're doing it in Revit for very specific reasons. And that's because of the data that we want to be able to pull out from it, and we want it to be adaptable, so if we change things, that data is available (3011 interview, 03/01/13).

For this interviewee, appropriate use of Revit at an early process stage was a thoughtful decision based on needed output. In a similar manner, Revit was used for its ability to allow a client to see a design in the way that the designers had intended:

> We showed them these shelves, had these proportions, and an opaque part, and that was part of the design. I know in traditional 2D representation, it would have been really hard to explain that to the client, well, this line here means that's out on that side, and I can see through it, where, they kind of got this immediately (3052 interview, 03/05/13).

The need to help clients to understand design has become not only designer driven, but also client expected:

> But clients today, are looking for, they just don't want a nice idea, the want to see it, they want to walk through it, they want to fly through it, and they want it tomorrow (2222 interview, 02/22/13).

Interviewees underscored the importance of communication through digital representation, not only for design work, but also for conveying intent to clients and other stakeholders. In a society that has become enamored with photorealism, digital representation gains value in relation to the process of design and approval. Digital representation allows the client to participate in the design of architecture by revealing ideas that once would have been undecipherable: "if you're not trained to, you know again, translate from the two dimensional to the three dimensional, we can look at a drawing and say, that's what I think it's going to be in three dimensions, where the layperson's going to have a harder time doing that" (3012 Interview, 03/01/13). The value of a virtual model extends beyond the immediate architectural practice.

This importance of digital representation in architecture has not only affected the work professional practice, it has also affected the perception of skills that newcomers to the community possess. Interviews with practitioners included a query regarding the influences that contemporary practice could or should have on education. When questioned about what students could be doing better, opinions regarding what students were not doing were expressed more often, providing more specific insight on the skills that differed from what firms were expecting.

Differing Skills

The value of digital representation within the professional community of practice also reveals a selection of skills that graduates appear to be missing when compared to the skills valued in a professional architect. In some cases, the absence of these skills may preclude the participation of young members in the community. Professionals assign identities to entering members based on assumptions of incoming skills, and when expected skills are not demonstrated, the perception arises that the skills have not been learned. Perception is key to the definition of these missing skills, as the interviewees had only experiential observations as evidence. The absence of certain types of activities may only indicate that students did not choose to utilize those skills, or have adapted different skills for similar use — not that they did not have them.

Sketching skills. Key among the skills that interviewees mentioned as less and less used by younger designers was sketching skills. Graduates tend to utilize digital representation far more than analog drawing skills, especially during the conceptual phases of design. While opinions varied as to whether the change in tool use was a good thing, most professionals agreed that for younger, less experienced designers, digital representation was the preferred tool for ideation, rather than sketching, summarized by one practitioner as "Some people generate ideas while they're in the software" (3051 interview, 03/05/13).

Observations by practitioners showed that designers may be developing abilities to utilize software for design thinking, rather than the traditional communication and recording medium of physical tools: "Thinking is very important, because now I think we've accepted the fact that they think using technology rather than using a pencil or a pen and sketching" (3011 interview, 03/01/13). In addition, when a software interface has a lower learning curve, designers may feel it can more closely resemble the abstraction of pen and paper:

> …then SketchUp came along, and that made it more intuitive, a little looser, and I can just see that now, it really is shifting to, it's all technology, that the sketching side of it is really becoming something of the past (3011 interview, 03/01/13).

However, for one interviewee, the issue of trying to use a digital tool too early seemed to be an indication that users were not using all their tools appropriately:

> I think that's an even bigger problem, these days with Revit, and users not sketching out and trying to solve the problem ahead of time before using the software (3053 interview, 03/05/13).

Interviewees described the absence of sketching as a missing skill as it related to design thinking. In the above quote, the interviewee states the problem solving should be done prior to using the software. For many, participation in the design process included using the tools of pen, pencil, and paper; failure to use these tools implied that the individual may not possess the same skills as someone who did use those tools, marking a difference in the perceived identities of these two members. Of note is the fact that while younger designers were not observed sketching, they were still following the traditional design process, although thinking and recording ideas were done digitally instead. Their identities did not appear to value the use of sketching in the same way that professionals did. Although the preferred method of participation in that design practice may have been sketching, they did not choose to align their activities with that requirement for central membership, or had not aligned learning trajectories that developed the skill.

Along with the preference for digital representation in ideation, interviewees also observed the tendency of recent graduates to focus on detail much too early in the design process, something attributed to tool choice:

> Yeah, if someone is working at their desk for a week, if what they've modeled is what I need, you really have to manage it, every couple of days…we're doing this condo building, and some young guy, he was modeling all the toilets. I don't need a perfect 3D toilet. I just need some sort of representation of a toilet. Four days later we don't have any wall sections. […] That's the other thing, you don't need to model every single condition, probably just need to draw it (3051 interview, 03/05/13).

A distinction is made in the above quote between modeling and drawing; two methods of representation that — for more experienced practitioners — have different uses and intentions. To model in three dimensions typically requires more effort and time than drawing in two; modeling requires both knowledge and manipulation of a digital model that seemingly, includes all the parts that a physical object would have, as opposed simple representative symbols. In this example, the younger designer was caught up in the software and the detail that he could include, rather than understanding the overall need for completed documents to express intent. The capabilities of the tool became more important than the outcome. The observation correlates with similar characteristics found during the literature review of student technology use in contemporary education. In this case, the realism of digital representation appears to be more valued than the intended use of the document it is meant to create: a two-dimensional drawing of the toilet locations in the building.

Symbolic representation. Also significant among the skills that are not shown in graduates is an understanding of the symbolic language of representation in two-dimensional documentation, specific to construction drawings that are used as contract documents. Despite the prevalence of three-dimensional modeling, communication of design intent between the architect and the builder is still mainly through traditional construction document sets. Less experienced designers have often been the individuals who assume roles of production as they learn their craft. Interviewees observed that graduates have increased difficulty in understanding the value and importance for translation of a three-dimensional idea into two-dimensional representation, specifically from a virtual model. This deficiency in output forces many senior architects to question whether students understand the language of representation that is key to architecture.

> There's so much work beyond that in documenting it as a 2D set of plans, it's huge…making sure that the dimensions make sense. Making sure that all the notes are there, all that stuff hasn't gone away. So it's a myth to think that, oh wow, put it all together in the model and then pop, we have plans. […] None of the notes, none of the thinking that goes along with it (3011 interview, 03/01/13).

There appears to be a disconnection in the medium used for communication, leaving more senior designers to assume that younger designers using digital representation do not know how to express intent in construction documents properly:

> Interviewee: I'm of the generation, that I have to have it on a piece of paper. Look at it and get the scale. That's another thing, kids they don't get the scale. It's not in scale.
> Researcher: I think it's getting lost. There's now an area of uncertainty, do they know this line is incorrect.
> I: There's nothing I can do. We're still in a world where we're not yet using the model, we're still printing in on paper. The line weight has to be right, it has to be legible - you don't know that until you print it out, looks great on the screen. On the screen the lines are green, yellow (3051 interview, 03/05/13).

Younger designers may do not design documents in the computer the way that they are printed Since much of the process of producing construction documents has changed with models as the source for the representation, communication is not a simple translation from the three-dimensional representation to the two-dimensional drawing:

> When you're modeling, you're essentially building this thing virtually. […] and all of the views are updated simultaneously. And you can view it any way you want. […] You're not really thinking in drawing necessarily kind of orthographic views. That seems to me one of the weirdest differences. And I don't know how students now, if they're introduced to modeling before drawing, how they understand the language of representation. […] I don't like to be told that your tool can't produce clear documentation. // I found that redlines were kind of hard because you're looking at in- progress 2D plots that didn't have all the background stuff turned off, or wrongly missing that, so you're just thinking, is that missing, is that a mistake, does that person know that's not supposed to be there. All I can respond to is what's here. And we have to have kind of a little conversation so the red marking isn't as good as, and maybe that has caused us to change how we work through the finalization of documentation (3052 interview, 03/05/13).

In an industry where construction document sets are legally binding contracts, architects depend on these two-dimensional representations to convey the accurate intent for design and construction. This established practice requires concise symbolic delineation that is understood by those in the building and construction industry. Marking corrections on progress documents is a traditional practice; senior designers understandably question younger designers when these documents are imprecise or incorrect, yet younger designers are often confident that a correct digital model is sufficient without the traditional notations, and, by implication, assigning fault to software when things are conveyed incorrectly. The common ground for corrections and revisions is tenuous at best, and the medium holds disparate value for each of these identities. If new graduates do not understand the reason for notes and symbols in orthographic drawings, and senior architects do not know what the capabilities are for output from a digital model, then these individuals do not place the same value on these reifications, or representations. In this case, digital representation restricts clear communication; the negotiation of meaning halts. The trajectories afforded by hand and digital representations appear to lead to dissimilar outcomes.

Photorealistic representation. In contrast to the disparate value of correct construction documents, one last major observation by interviewees was the tendency of recent graduates to focus on the photorealistic images afforded by digital representation. Similar to the issue of less sketching and more digital representation, graduates tend to present more completed presentation models and images, with less evidence of ideation and process work. The finished product appears to be more valued by students than the process to get there.

> [The] change in the last few years has been a huge advancement in presentation ability, ability to make things look believable. That comes across more in interviews, do you know how to put this together? There has been such emphasis on presentation. […] Now there's an over focus. Give me a section of what that meant, diagramming, how did you get there. [Show] the full range of the project development, don't focus on the technology. There needs to be a base level of the understanding of these things (3151 interview, 03/15/13).

Students spend so much more time on final representation that they fail to show the parts of the process that holds the most meaning to senior designers, as described by one interviewee: They are captivated with imagery. [But] they don't know what they see" (3141 interview, 03/14/13). Presentations show more images of realistically rendered spaces than diagrams that document initial concept ideas and design development in process. For practitioners, the photorealism and the effect that can be achieved is not evidence enough of critical design thinking:

> They think in terms of end graphics, not about construction. As the industry has led toward, you have to be a designer, not just a drafter. You have to put a drawing together, you have to design it, you can't put parts and pieces together, you have to show it. (2141 interview, 02/14/13).

The interviewee describes his observations that students think more about the end result of the rendered work they show than the process they used to arrive at the solution. Students have allowed the realism of digital representation to convey the bulk of their design work. Time and effort to create a virtual model may outweigh the importance of the learning and design required to create the depicted space, or the tools now favored for ideation do not facilitate the capture of progress imagery. Professionals value the evidence of process (latent content) created in ways that students may no longer use or value. Logically, however, if students are doing their thinking in the computer in real time, there will be less of the process captured for later study.

Desired Skills

During the case study observations, three surveys were administered as a means of assessing beginning and ongoing learning, as well as to determine what students thought were their achieved competencies in the course. The answers to multiple choice and short answer questions reveal trends in what students believe about learning technology in the context of preparation for architectural practice. These early perceptions give some insight into the early formation of identities in the field of architecture. Most significant of these beliefs were connections to studio instruction, software use for design practice, and idea visualization.

Technology instruction connected to studio classes. Students expressed a distinct desire to have the technology processes and learnings connect to the context of their concurrent studio classes. Ninety-two percent of the students who took part in the progress survey (See Figure 4.1) felt that what they were learning in class would help them to do better in studio work (Progress Survey, 02/27/13). At the end of the quarter, many felt that they would use the knowledge again and improve their skills in future studios, and would have liked additional instruction:

> I think that everything we learned was very helpful. I think learning to do section cuts or other things that directly apply to studio that we will always use would have been helpful because I still don't know how to do that and I think that is holding me back from making my models in rhino (S1, Last Day Survey, 03/13/13).

For the above student, further connection to studio might include specific instruction on how to achieve the views needed in the studio class, but as described by one student, a connection appears to have been achieved: “I have used everything that I have learned in this class to help me in studio” (S2, Last Day Survey, 03/13/13). Skills learned in the technology class were transferred to work in the studio.

Learning for professional practice. As expected, students also thought that technology, in terms of the software they were learning in class, would have an impact on their education and design learning for professional practice. Eighty-five percent (See Figure 4.1) felt that the knowledge would prepare them for professional practice, and eighty-one percent thought that what they were learning in the class would help them understand how technology could be used in the design process. At the middle of the quarter, eighty-five percent (See Figure 4.2) still hoped to learn how to improve their skills with the software (Progress Survey, 02/27/13). At the end of the quarter, many students articulated the wish that they had learned specific software used by the industry: “Maybe a little time to use other programs other than Rhino. Revit, SolidWorks and AutoCAD for example…(S4, Last Day Survey, 03/13/13). Specific requests for software used in professional practice were clear: “I was hoping to learn AutoCAD and Revit. I was also hoping to learn some more about Photoshop, but I realized it is not practical to fit all of this in one course” (S5, Last Day Survey, 03/13/13). And finally, one student questioned the software chosen to be taught, and didn’t feel that there was a correlation given to its applicability in the design or the profession:

> I was hoping to also skim through a few other modeling programs on the market and CAD. This class seems dedicated solely to Rhino yet didn't tell why Rhino should be in focus. No comparisons to other programs were given (S6, Last Day Survey, 03/13/13).

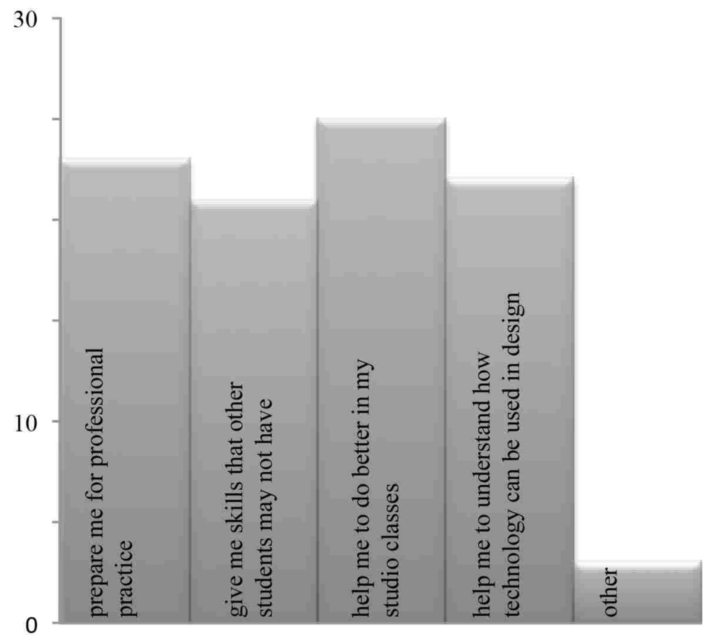

Figure 4.1. *What I'm learning will...*

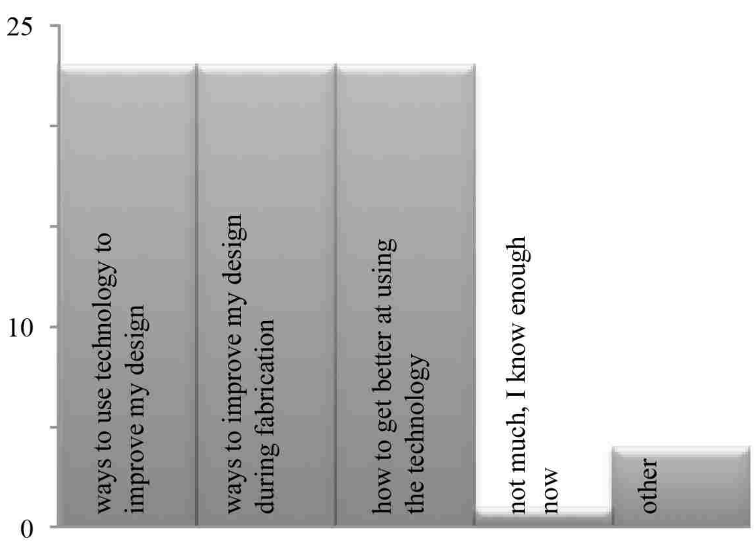

Figure 4.2. *Still hope to learn*

Improved visualization ability. Finally, one last trend in student thinking emerged; students considered the ability to improve visualization through digital representation as an important skill to learn. At the middle of the quarter, eighty-five percent (see Figure 4.3) agreed that the computer software would help them to visualize designs in ways that sketching could not, but only forty-four percent (See Figure 4.3) felt that using technology was necessary for good design (Progress Survey, 02/27/13). The affordances of the software's visualized output were expected to help them realize what they had designed, as expressed by one student: "This program is good for modeling structure and seeing how it all can come together: (S9, Last Day Survey, 03/13/13). Students used digital representation to help them understand their ideas as three-dimensional space:

> Because it is a great tool that facilitates the work by giving a more realistic view of the space. The advanced and high quality it provides helps me to develop my project to more complex levels (S11, Last Day Survey, 03/13/13).

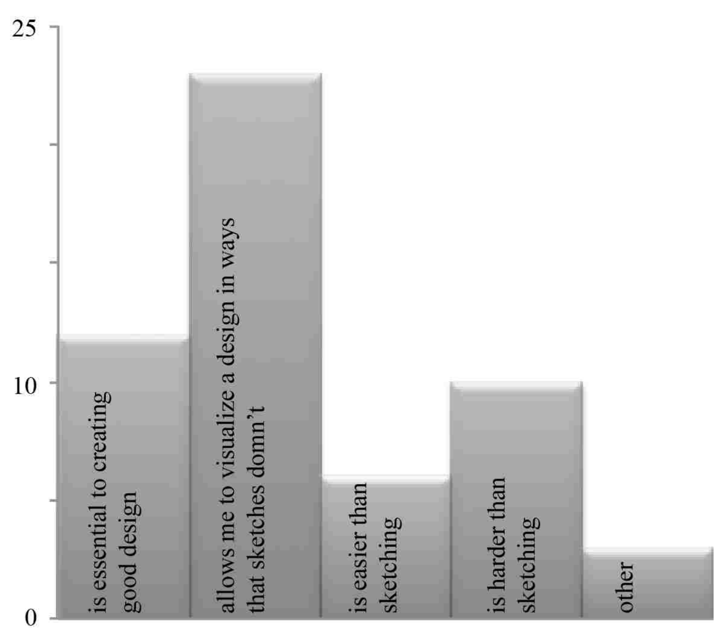

Figure 4.3. *Using tech*

The day of the progress survey, the students asked the instructor to teach them how to use Flamingo, a rendering program, although it was not on the syllabus. Most that requested it did so because they wanted to use the software to create renderings for their final studio projects.

> Teacher: […] Any questions? Yes?
> Student 1: Are you going to teach us Flamingo?
> T: Do you want to learn flamingo?
> Student 2: Yes.
> Student 3: Yes.
> T: I can give you a lesson in Flamingo next week, or do you need it sooner?
> Student 4: Next week is fine.
> T: What do you want to learn? Trees, lights, interiors, etc.?
> Student 5: All of the above.
> T: If you really want, you can take a class called 481, modeling and rendering, and you'll dive really deep. I haven't used Flamingo since last summer. If you want three hours of Flamingo I can give you three hours of Flamingo next week.
> Student 6: Why haven't you taught Flamingo?
> T: Why? Because I figured, how many of you bought Flamingo? That's why. Because I don't think you guys would have bought it.
> Student 7: What do you use to render?
> T: Flamingo. I don't know, not so good at Vray, but I know Flamingo (Classroom Observation, 02/27/13).

At the end of the quarter, it was clear that for many students, using digital representation to help them visualize their ideas was an important asset. When asked why they wanted to learn Flamingo, photorealism, presentation images, and high quality renderings were the reasons: "We need better renderings" (S12, Last Day Survey, 03/13/13). The need for efficient and realistic methods for rendering seemed to be important, at least for this case study class, as described by one student: "Seems like a more effective way to render than the built in Rhino rendering" (S13, Last Day Survey, 03/13/13). The quality appeared to also be of concern: "It seems to provide a simple interface for mapping materials when rendering in rhino and seems to produce higher-quality renderings" (S14, Last Day Survey, 03/13/13). These statements seem to parallel the observations made by interviewees about novice and incoming individuals to professional practice over-emphasizing photo-realism in their portfolios. Examples of finished digital representation to visualize a space were observed to be more common than depictions of the process work.

The new student identities that have fostered high skill in photorealism and adept use of software for digital representation have prompted the evolution of the design team dynamic. When external pressures force (and internal decisions prompt) firms to incorporate BIM and advanced digital representation methods in early design phases, the need for knowledge and expertise in both construction and software has paired senior architects and junior architects in collaborative design efforts.

A New Typology for the Design Team

One of the most significant developments in professional practice that has been documented in literature is the emergence of the paired approach in design teams (see Chapter 2). In many of the interviews, this adjusting social structure was also observed. During the analytical coding process, excerpts describing the activity of team members as "pairing" occurred twenty times. While the number itself is not as high as other codes, it is the only analytical code that indicates a change in community practice that involves explicit change in the social structure of the office:

> Interviewee: You know, on building projects, and even on planning projects, if they know SketchUp, that's a great entree, because there's a lot of need for SketchUp. And then what the trick is for that person to be a contributing member on the team, doing SketchUp, which can sometime be months of, just basically, rendering, and drawing things that somebody else is directing.
> Researcher: production.
> I: Kind of production level design, yeah. And not to get pigeonholed into that. And we've had just a series of people who are two, three years out of school, that have been that role, and they get to jump around a bit, from project to project, because we have a lot of early stuff that we're studying, or we have a study over here or a study over there, and they have the SketchUp skills, they can be really contributing to the project (3011 interview, 03/01/13).

For some, the pairing of material knowledge expertise with technology expertise was not a desired outcome:

> Researcher: So in terms of working in a team, is that something that would happen here, a group of people would be around a monitor, and one person would drive essentially, and other people would say things?
> Interviewee: I would have team people do that. I have seen that especially with senior designers, working with younger staff, saying, hey why don't you do this - and they're standing there in the corner - and I cringe every time I see that.
> R: Would you prefer that each team member is able to do what they need to do in the software?
> I: I think that's ideal. I think it's kind of unrealistic. Especially for a lot of older staff. Senior, staff (3012 interview, 03/01/13).

But the efficiency of the collaboration seemed to be of greater value to the business of architecture:

> And so, you know, one of the younger guys is doing that right now. He's working up a wireframe and I'll manipulate the views, and then I'll overlay it, and do the changes on it, and the combination of those two methods is faster than, ah, one of them by themselves (2201 interview, 02/20/13).

And in some cases, pairing would occur out of the reluctance of some designers to learn how to use the software, despite what that might mean to their own positions:

> [Interviewee: They do know what they're doing, and some of them may be very interested in it [technology], but they don't know how to do it.
> [Researcher: because they don't have the experience
> [I: We have people that say, you know, I want this 3D model walkthrough, and I say, sit down and do it. I don't know how to do it, I shouldn't have to know how to do it. Well, okay, the person that is doing it today, for you. Fifteen years from now, when they're in your position, they won't need to have that done (2222 interview, 02/22/13).

Professional practice continues to adapt to the importance placed on digital representation by clients, other collaborators, and students in the industry, altering the membership requirements of both boundary and insider trajectories to accommodate the need for technology skills in evolving practice. Whether experienced architects do not have the technical expertise or inexperienced architects do not have construction expertise, the design team has developed to bring together the needed members to provide the requisite knowledge and ability.

As software advances in complexity and those members with content knowledge continue to lack the training in technological representation skills, members who are capable of bringing these skills to the team are able to participate in the design process more often, and will likely become more of a rule than an exception.

Mismatches in community practice and identity

In each of the study's two main components, the use of digital representation has forced renegotiation of meaning for practice within the communities examined. However, these new meanings have not necessarily aligned with each other because the communities have developed separately from each other as a result of differing uses for technology. The historical tensions discussed at the beginning of this study in terms of interest and contexts continue to prevent the alignment between the communities of education and professional practice. Due to the complex nature of each of these communities and the tools they use, participation shapes each practice according to the dynamics of the individual elements that are a part of each community: individuals, tools, activities, meaning. While professional practice has seen digital technology negotiate new meaning in the design process through analysis and reflection on ideas, students have placed an importance in the technology for its effectiveness in producing finished representation. The misalignment between the meaning and use of digital representation repeats itself in a mismatch of student and professional identities. The identities that students form while in school not only differ; the influences also do not motivate students to learn the skills that are part of the identity for membership in professional practice. As a result students may not be developing the skills full complement of foundation, technical, and technological skills expected by professional practice, and this may lead to a perception of diminished skills.

Digital representation use. Based on interviewees' responses, digital representation has become significant in the meaning that it can bring to the design process. When used in the design development phases, it can facilitate informed decisions and more comprehensive exploration of the alternatives in the design process. Digital representation can provide analytical information and help designers predict areas where coordination issues occur within a virtual model (Birx, 2005; Scheer, 2011). Content expertise in the construction industry gives meaning to the digital model by allowing practitioners to interpret the information it provides through reflection and analysis. The importance of digital technology within the design process is negotiated through its utilization for further developing design. The computer aids problem analysis in professional practice (Abdelhameed, 2006; Chen, 2001). Designers use a process of study and revision, making changes as they analyze results. Individuals who use digital representation in conjunction with content knowledge are able to design and manipulate the digital model. Their skills define the identity of an architect with primary membership in contemporary practice (Holland & Lave, 2009).

In contrast, student identities focus on the affordances that digital representation brings to final visualization of a project. In literature and in the case study observations, students used digital representation to aid external visualization of their designs. Rather than knowing in their own minds what a design would look like, they place meaning and understanding in the output of the software, waiting to manipulate views of the model in order to "see" it. The question then arises whether students come to internally visualize their ideas if they learn to depend on the computer to reveal views and possible outcomes to their designs (Angulo et al., 2001; Cho, 2012). Instead of learning to use digital representation to aid in problem analysis, students use it as a tool for solution analysis, to determine if they considered their designs correctly (Chen, 2001).

Identity. The development of student identities is even more complicated by the emergence of the typology of the paired approach in design teams. (Groleau et al. 2012). With or without organized team development, intern architects find themselves working with senior architects, contributing knowledge and ability in order to both visualize and analyze evolving design. Senior architects rely on younger architects to give substance to the design process through digital representation, perpetuating the expectation that technology expertise can lead to immediate participation in the design process.

These mismatches in identity are likely the reason that graduates do not always meet the expectations — but still may exceed the capabilities — of professionals. However, if changes in technology use for professional practice are not specifically addressed in the pedagogy of architectural education (including the Intern Development Process, or IDP), how are students to know what direction their focus should take? If the changes in the professional community of practice are not reflected in the educational community through an instructor, students will attribute meaning arbitrarily or based upon their own impressions of what skills are required to be an architect. Motivation to assume a particular identity will be based on the values and actions given meaning in the community (Holland et al., 1998; Nolen & Ward, 2008; Wenger, 1998), whether gleaned from specific individuals or overall impressions from media.

Chapter 5.
Communities in Flux

The most significant finding from this research is that the practice of architecture is undergoing significant change. The definition of expert architect has evolved to encompass both content knowledge in construction and technical knowledge in digital representation. Almost every respondent noted a substantial adaptation of firm processes to the needs of the industry. While the final activity — or joint enterprise — of design has not changed significantly, the processes and tools used by the community have changed, as well as the perceived value members ascribe to them. These changes in turn continue to influence the identities of the individuals in each community, as well as the relationship that exists between professional practice and education. A transition in valued practices is inevitable. Architecture as a community is changing; realignment of practices and expectations must occur. In order to keep the transition from disrupting the conventions that support the industry of architecture, educators should become aware of the ways that the professional community is changing through adaptation, tool use, membership and identity in order to incorporate comparable scaffolds in learning that help students establish appropriate identities throughout their careers. At the same time, practitioners should understand the complexities involved in motivating student selections of learning opportunities that privilege certain skills over others, so that they can better train and develop incoming members. Furthermore, the use and value of digital representation in both communities will continue to change, and this necessitates an ongoing process of reassessment.

Adaptation in the Community of Practice

Wenger (1998) described the negotiation of meaning as a process, "at once both historical and dynamic, contextual and unique" (p.54). The ongoing and often unpredictable nature of this negotiation forces changes to the context of architecture in ways that may have unintended consequences (Kalay, 2006). As technology in design has advanced from two-dimensional representation to data-driven three-dimensional digital representation, software use has increased in the professional office, often at a pace that firms are not prepared for. Even with careful planning, the integration of digital representation has not been simple, and requires adaptation. Its evolving use as a tool implies that negotiation of the meaning it holds will also change (Wenger, 1998).

During data coding, analytical codes were defined that exemplified the changes occurring in the community of practice (see Table 3.2). The code "change in practice" was used to denote any excerpt that described a change is office process due to digital representation (see Appendix D), and was only second in frequency to "tool use" with fifty-six occurrences in interview data. The implications of this coded theme to the community of professional practice are discussed below.

The importance of digital representation in practice. Digital representation has moved beyond symbolic depiction at the end phases of the design process for documentation to a vital part of concept and design development. The external visualization that a virtual construction model can provide for problem analysis and design decisions has become invaluable in the architecture, engineering, and construction industry (Birx, 2005; Scheer, 2011). Professional practice can negotiate meaning with this tool in ways that could not have been done with previous two-dimensional CAD representations that were only digital versions of analog drawings.

> What is cool is that when you get all those entities, structural, mechanical, electrical, plumbing, all into the architectural BIM model, a lot of the coordination, happens, it's obvious, what you have to coordinate. You find it earlier. You work around it. […] But the coordination is at such a sophisticated level that you need to have that experience of understanding how things kinda go together (3011 interview, 03/01/13).

This interviewee describes one of the most common uses of BIM, interference checking. When the model is used this way, collaborators can see the areas where the varying designs and decisions will impinge on each other in the physical world. The meaning of digital representation is negotiated during the design process, in the way that it is used to inform an understanding of the design in progress (Abdelhameed, 2006; Chen, 2001; Schon, 1983). Expert architects use their experience and knowledge to attribute meaning to the external representation — coordination issues, lighting studies, etc. — in a sense, adding meaning in the future materiality of the digital representation. They understand the significance of what is viewed, and how it impacts the project in process. Digital representation in each phase is a reification of the design process (Nolen & Ward, 2008; Wenger, 1998). One interviewee summarized, "Seeing it go from diazo to now, the design process has not changed, just how we interact with the technologies" (3151 interview, 03/15/13). Professional practice, in the sociocultural sense, has redefined the negotiation of meaning for representation processes within the community. In the activity of participation and reification, the community changes as it adapts to digital representation (Greeno, 2006; Nolen & Ward, 2008; Wenger, 1998).

Technology has changed the community through the evolving selection of tools for practice. Interviewees observed that there are now more tools to choose from when "doing" design. Which tool is appropriate is defined by the meaning negotiated with that tool, and its use in the process of design: ideation, analysis, reflection, and solution.

> However they get to the technology to present ideas in design is still kind of the same. SketchUp, Revit, same steps in the process are still there.// I would say in the early phases of a project I think it's still a tool. […] it will help you communicate, envision stuff, look at different situations, and it might instigate certain lines of thinking. But I guess I think that it's still a tool (2261 interview, 02/26/13).

This interviewee describes that design has not changed due to technology, just the tools used to do design. Technology use in design during early phases of design is a tool for aiding thinking. Advancements in technology have brought the affordances of digital representation to new levels of ability, but the use has not changed significantly from other tools, in that the tool negotiates and supports meaning made by individuals. The tool does not make meaning, it allows those using it to make their own.

Giving meaning to the digital model. Most telling about the professional meaning associated with digital representation is an understanding of the materiality of a virtual model. A digital model is not considered an end product, but a tool with which designers are able to consider their design ideas and what adjustments should be made. Schon (1983) characterizes this as a process of reflection — a conversation with the situation, where changes to the design lead to implications for other changes that may create a better solution. The design process is then negotiated in the context, implying that meaning for the individuals involved is defined by participation, and the knowledge inherently involved. Professionals understand the potential effects of decisions and adjustments to the design, and make them in order to improve the processes, output, and project. The stated requirement of content and construction knowledge for effective and efficient BIM use is clear. Without it, users cannot know what manipulation of the model will entail. The digital model does not have meaning without the material it represents.

Deriving meaning from the digital model. In contrast to professional meaning making with digital representation in the design process, an unfamiliarity with the significance of detail and building construction marks beginning student use of digital representation in education, specifically in the motivations and intentions for software integration. Students negotiate meaning in examining a modeled solution, deriving the meaning from the visual model and what it reveals about their design. The model is used for communication, for others and for themselves. Meaning is negotiated from the final product, rather than in the process. Implied tool use is for discovering meaning, rather than for making meaning. One student stated, "[I] don't make a computer model till end of design process, beginning of board making process" (S15, Last Day Survey, 03/13/13). Students utilize the digital representation to provide them with views of their designs that they may not have considered or imagined: "It allows me to understand my design with precision" (S16, Last Day Survey, 03/13/13).

In the case study surveys, students articulated that the affordances of digital images for visualization of a design idea and the presentation of those ideas as primary reasons for the usefulness of technology in design. Chen (2001) noted the inclination of novice designers to use digital representation to achieve an understanding of the sense of space. Earlier proponents of computer use in the design studio advocated visualization benefits as reasons for digital representation integration early in architectural education (Ataman, 1999). However, this approach may not prompt students to select tasks to develop skills that promote strong internal visualization abilities, as students learn instead to rely on the digital representation to attribute physical meaning to an idea (Angulo et al., 2001; Kendir & Shcork, 2009).

Learning digital representation for design process. Students extract meaning from their community through the actions and values created in context, and the use of digital representation is a product of that world (Holland, 2010; Nolen et al., 2011). In studio contexts where the significance of digital representation is not negotiated in a way similar to professional practice or at all, students will form their own meanings and values, selecting to learn and do what they feel is most important for their personal motives (Holland, 2010; Nolen et al., 2011) despite the best intentions of their instructors. However, when given reasons and explicit examples of how digital representation can be used in the process of making physical objects — similar to professional practice — students begin to learn integration in process, not just at the end.

Rugemer and Serrato-Combe (2008) describe the success of optional digital seminars with curriculum designed to teach skills to correlate to concurrent studio design problems. By providing students with specific instruction on actions that would help them to accomplish tasks in each step of the design process, students were able to apply the software learning directly to the work they were doing in design studio. Students that combined these techniques with their design solutions were able to develop more complex solutions and to develop their schemes further than students who did not choose to participate in the digital seminars. In a study by Carraher (2011), studio assignments that introduced students to digital commands and requirements were created to be similar to physical tasks encountered in the studio. Students began to understand that successful digital models could not be realized if they did not know how to make them. This approach grounded digital learning in the physical context.

Similar to the studies by Ruegamer and Serrato-Combe (2008) and Carraher (2011) the students in the case study worked on projects that required a combination of digital modeling and design process, as well as physical construction. Students did not only make digital models, they had to use the models to produce parts to create the models physically as well. The successful outcomes of some student work and thinking indicates that mediation by the instructor may be instrumental in providing negotiation of meaning that includes materiality and understanding of more than digital shape and form. In the case study, as the class progressed, students were observed using digital representations in ways more similar to professional practice: “I usually have concrete ideas in mind and trial-and-error with them on the computer. That means, not every idea has been realized" (S17, Last Day Survey, 03/13/13). When asked about how they approached design, this student described the development of a process that incorporates the software as a tool to explore ideas, similar to the use that professionals incorporate for reflection and refinement during ideation. "I think once I get even better at Rhino and able to design faster in the program I will use it to visualize an idea (S18, Last Day Survey, 03/13/13). Similarly, this student anticipates using software to explore ideas, rather than just to communicate a finished solution. The meaning provided by both the instructor and the fabrication activities evolved the classroom community to one in which digital representation was used in the design process, as a tool for ideation and analysis, and then tested in physical form. Students began to combine their learnings in materiality with their understanding and design of the digital model. Their identities began to include the formation skills that coupled basic knowledge of construction and material properties in the process of using digital representation for design, similar to professional identities.

Change in Identity

Architecture has renegotiated the identity of a professional architect through an emphasis in digital representation. This in turn has reshaped student motivations for learning in representational technology. The typology of the paired approach in professional practice both implies and enables different points of entry into membership in the community, when primary membership is inclusion in the design process.

> Interviewee: But we've usually got one or two people in that [rendering] position. That they're doing that work. And it's a great learning.
> Researcher: I was going to say it's probably a developmental place to be, you're sort of contributing what you can, and then learning and contributing more as you're able to so, with a little bit of, with guidance as well.

> I: It works pretty well. We had one guy, when I joined three years ago, he had been with us for about six months, and that's exactly what he was doing, and he kept doing that for another year or so, and now he's on a similar project to this one, which is a from the ground up high-rise, and he's gonna stay on it. I mean he's been doing the SketchUp, but he's also got the - the technical experience now that he's contributing and worked construction a little bit (3011 interview, 03/01/13).

Since the discipline has always focused on experience as knowledge, the new typology of pairing changes the dynamic of the community and the meaning through which individuals can negotiate their identity, and how they are positioned within it (Nolen & Ward, 2008). Ability at digital representation can facilitate the creation of knowledge (Wenger, 1998), as professionals use data to inform the design process. Content novices who are tech experts can now begin entry into primary membership in a new way by working directly with senior members and designers (Groleau et al., 2012), accelerating the traditional trajectory for primary membership. Since the identity trajectory of a professional can be considered as insider, the identity most influenced will be that of the inbound and boundary identities — the student and intern.

Emphasis on digital representation skills due to their increased importance in professional practice may be the reason that students place emphasis on the value of digital technology skills. Students perceive technological ability as necessary to membership in the professional community and orient themselves for trajectories that will include technology learning (Klinger, 2009), in an attempt to mediate what is valued within their own community and future communities. Evidenced in the classroom observations was the prevailing attitude that learning in technology is vital to participation, setting a norm for digital representation use in the educational community. This attitude was also stated in the interviews, in conjunction with the hope that students might begin to prepare for technology use in during education:

> Maybe not now, but within the next few years we'll probably expect everyone coming out of school to know how important Revit is. We train people how to use

> Revit in house, because we customize it for our own purpose. But, what we found it takes, a person two or three projects before they're really adept at using Revit, and so if they've gotten two or three project cycles out of the way during design studio, rather than learning on the job, then it's just a matter of learning how we utilize it, how we customize the program (3012 interview, 03/20/13).

Professionals would rather have students learn digital representation skills in conjunction with design studio projects, preparing students to apply these skills in the office environment.

While professionals understand that digital representation, especially BIM, requires content knowledge, when the teaching of software skills is not connected to studio learning and that learned content knowledge, students do not have experiences that anticipate those that occur in the workplace. Motivation is then left for each individual to negotiate based on the identity that they wish to achieve (Holland, 2010; Nolen & Ward, 2008). From a student's point of view, digital representation is given prominence in professional architecture. In order to join that world, skills in digital representation have become a means to entry. Students invest themselves in the worlds where they seek identity (Holland, 2010), and may find themselves maintaining "multimembership" (Nolen et al., 2011) in order to resolve their identities in more than one community. They may choose certain aspects of identity that are norms for participation in the educational community (long hours and physical massing models) and yet develop other aspects of identity they believe is needed for professional practice but not required by instructors for studio success (like expertise in photorealism).

During education, the pressure of appearing to be a "good designer" among peers is often wrapped in well-rendered presentations. Curriculum places importance on presentation with classes that require digital design layout skills. In this community context, students naturally negotiate identities that are defined by the educational environment (Nolen et al., 2011). One student in the case study wrote, "This class works great with studio already. It is giving us familiarity with using the software we use to make our drawings for studio" (Progress Survey, 02/27/13). Finished images for design process seem to be the focus, also described by this students when asked what could be improved in future classes: "I feel rendering deserves a little more time" (S19, Last Day Survey, 03/13/13).

In the short ten week class, many students wanted more time spent on rendering skills than the three weeks they were given. One student wrote, "A little bit more on rendering could be good. Not sure what to cut out" (S20, Last Day Survey, 03/13/13). Given the opportunity to express what other skills they would have wanted to learn, students in the case study observation emphasized rendering and manipulation of the software used for rendering Rhino models. As discussed in the previous section, identity formation can be viewed as an ongoing process of becoming, either for entry into a future community, or to continue to maintain membership in an existing community. When focused on the photo-realistic affordances of digital representation, as in the case of the classroom observed, the surrounding social context of education may compel students to choose trajectories that emphasize technological mastery over building fundamental design skills such as developing knowledge of building assembly.

The skills needed to use BIM have created new points of membership into architecture's community of practice. As described by Wenger (1998), each type of skill has meaning ascribed by the use and reification of the skills within the community. With the emerging importance of BIM learning and ability, expert facility in the software has increased in value. However, with this change in tool use, the professional community has found that within the design process, tools must be appropriate to the task at hand.

Misaligned perceptions between communities

The results of the research study underscore many of the assertions in literature about the influence that digital representation has had on the architectural discipline. Both professional practice and education have made adjustments to the importance that is placed on this specific use of digital technology for architectural representation. Each community negotiates meaning for the activities that support and require digital representation skills, but as demonstrated by the results, that meaning may not be shared. Alignment in a community requires “shared implicit understanding of concepts” (Greeno, 2006, p. 87) from which to negotiate meaning. The misaligned change in valued skills may be the filter that suggests diminished ability in contemporary graduates to professional managers.

What has been missing from previous studies of technology influence is the framework to understand the results of these changes. Practice changes through activity and the reification of community processes that members allow to happen (Oliver, 2011). Architecture has allowed the changes in the discipline to occur, with or without intention. One interviewee recounted an American Institute of Architects (AIA) meeting during which members of the building industry outside of architecture shared their opinions of the direction of the discipline and its education:

> [They] basically said, you guys, if you guys as architects don’t wake up, and see how the profession relative to the amount of work that the contractors are doing in that office, or the integration of contract, or whatever it is, you’re going to wake up and find out that somebody else shaped your profession and you didn’t. So you need to decide, proactively, what do you think it’s doing and where do you want it to go? (3051 interview, 03/05/13).

The growing use of BIM and digital representation in collaboration in the construction industry is changing the nature of design influence. The importance of the digital representation when used solely by construction trades may overshadow the significance of good design as fewer people understand the importance of using the right tool at the right time for the design process.

Tools with the wrong affordances can diminish the facility and ability of the individual using them to do a task efficiently (Kalay, 2009), an observation made in the interviews. As digital representation tools are used more and more than traditional analogue tools, the need for proper instruction in all valued skills and tools grows; the professional practice seeks members who can use each tool for the appropriate purposes, maximizing resources and abilities for the office, rather than restricting an individual's usefulness:

> I would say yeah, technology is just another tool. If you don't know how to process, or use another tool to solve the problem, then there's an issue there. You're' just relying on one tool then you become specialized, and you're not really a generalist anymore. I think of this firm, we prefer those types of people that are generalists, that are a broad band of skills (3053 interview, 03/05/13).

Depending on the size of the firm, individuals are sought for the value that they can bring and the resources they represent. Too narrow a skill set may not be useful enough.

> Interviewee: Everyone in the office draws, really proficiently, by hand, and I think that that's something I wouldn't say is an absolute, but it been pretty valuable for us to have that capability.
> Researcher: And you'd look for that capability now. Would you?
> I: I think we would, especially knowing what we know about Revit and it's limitations. And the value and ability to sketch quickly, and example of that is that your sitting down, at a table having a conversation, and if only one person can draw, it's a one-sided conversation. And because we're trying to get more precision in our communication about space and form, I don't know how else to do it. Without wasting more words than I already wasted. I think it's really important for me to know what other people are thinking, and there's no delay. Are we seeing the same thing, that we're imagining, or am I going to come back after 3 days of intensive BIM modeling and go no, that's not what I though you were saying (3052 interview, 03/05/13).

Despite the prevalence of digital representation, sketching has not lost its value as a quick and efficient tool for communication:

> Researcher: So, does sketching still have a place in the …
> Interviewee: Absolutely. I mean, you know, its still the fastest way to communicate an idea. And I still think it's the fastest way to work things out. You know. It's also the most, I would say, this is the one issue I've seen with technology is, until we learn how to work totally in the digital world, umm, or

> virtual world, it's not ever going be to be as social as the physical sketching. // I think, you know if you become too dependent on the tool for your process, then that tells you something about your process. Process should be - it might be more efficient using a computer, it might be more efficient using pencil or a pen or a model, but you know. The process itself should be more independent of that. I mean, you should be able to design in your head. You're just giving physical form and enabling process (3012 interview, 03/01/13).

Firms are searching for people who understand the appropriate use of the tools in the architectural trade and the abilities to use them all. Digital representation and the use of technology in the design process are rooted in the knowledge of materiality in the ultimate construction of the project.

For today's graduates, the abilities they do bring are often misunderstood or too different from those valued by professional practice. Interviewees revealed that novice designers constantly appear to think and design in different ways from senior designers:

> Interviewee: I think learning how to sketch, is what's missing.
> Researcher: Probably.
> I: But, you know, technology is a great tool, and the kids know how to use it.
> R: Do you think that it's started to force them to see differently too, though?
> I: Yeah, I don't think they see as well (2201 interview, 02/20/13).

The lack of tangible, physical evidence of design thinking appears to imply a differing skill set. The consequence of this is not yet understood by professional practice.

> Interviewee: Fifteen years ago, I would have said, absolutely, if you're gonna hire somebody, they have to be able to draw, they have to be able to communicate by hand. It's totally wrong if they would design in AutoCAD at that time. With SketchUp, there's been a bridge. Although I haven't learned SketchUp, and just from looking at it, it's still not that direct connector, the brain to the hand.
> Researcher: There's an extra step. How will I make that, do that.
> I: But the result of what I've seen come from people, I'm a believer that it can be done different ways. I worry what we're losing (3011 interview, 03/01/13).

Students' tendency to focus on the visual affordances of digital representation emphasizes the portrayal of skills that do not always include traditional methods of sketching for ideation and design exploration. Many prefer to move quickly into a digital modeling, spending less time in two-dimensional representation. Ivarsson (2010) described the approach that students take with digital models as one similar to working with physical models — viewing overall and in a bird's eye perspective from above, not from within or from a real approach. The lack of abstraction in student work is often a concern for more experienced designers, but new ways of thinking may be replacing more traditional methods. This lack of external design process and lack of development of analogue perspective cognitive processes may lead to the perception that graduates have not learned everything they should because of "technology". Further research is needed to observe and analyze the ways in which learning designers are now utilizing their digital tools.

Change in Community Membership and Participation

Architectural practices have been reified at the points where digital representation is used within the design process. Digital representation creates new output, and this new tool changes the nature of the activity of design thinking and making (Wenger, 1998). Traditional skills are still valued, but the increasing need for skills in digital representation have changed the requirements for membership in the professional community:

> They [senior designers] know what to draw and how to draw it. What they don't know today is how to have Revit draw it, or AutoCAD draw it. So we're in the same transition, that you had when you used to have the drafting room. So, you know, now, these people, they can draw, but it's not worth anything anymore. What are we gonna do with this hand drawing. We need it in Revit. And so we're facing, that transition (2222 interview, 02/22/13).

The mismatches in tool use and meaning negotiation have compelled professional practice to adjust organizational processes to manage the importance gained by digital representation within the culture, as well as led to perceptions that newcomers are not as well prepared as they should be. When required skills are not found in a single individual, design teams form to facilitate tasks through a pairing of individuals with complementary abilities (Groleau et al., 2012; Lassor &

Pocorobba, 2013). This may compel students to select alternative trajectories for membership in professional places (Wenger, 1998), and focus on the mastery of digital representation first, since there may be opportunity to join a paired team.

However, the change in the profession is influencing trajectories of entering newcomers in such a way that some identities are on trajectories that result in the desired balance of technological and traditional skill:

> It's starting to become pretty standard, that even those people have great ideas, who have great minds, there's enough of them out there that when we're interviewing, they have that ability and they have the technology behind them. And it's like, we don't have to make a compromise (3011interview, 03/01/13).

As practices in both communities become similar with time and explicit instruction, inbound and insider trajectories lead to similar identities (Greeno, 2006), as individuals align to valued skills. The rise in digital fabrication teaching continues to link the digital and physical worlds in ways that allow students to construct experiences in materiality similar to building construction (Ambrose, 2011; Asanowicz, 2007; Chiu & Lou, 2006), as briefly described in earlier in studies by Carraher (2011) and Ruegemer and Serrato-Combe (2008) and explored briefly in the case study. Students can learn to use digital modeling both in the design process as a tool and as a representation. Given the right opportunities, student motivations can lead to trajectories that emphasize skill building that meets professional expectations and needs. Further study is needed to determine if this type of technology integration will motivate students to develop these skills. Opportunities for self-reporting, interviews, and ethnographic observation to understand student attitudes, goals, and thinking could be utilized in conjunction with current analysis of student artifacts to provide a more complete perspective of contemporary architectural learning. Exploration of students themselves, rather than the artifacts they create, may help direct the integration of technology in design that supports their learning in a ways that provide deep and meaningful knowledge internalization, preparing them for membership in the professional communities of architecture that are in constant change.

Chapter 6.
Conclusion

Implications and Learning Opportunities

In an effort to uncover strategies to improve digital technology integration in learning, this study set out to explore how the advances in digital representation have affected professional practice, and how these changes may have influenced student identities in architectural education. Taking these changes into consideration, the study focused on these questions: 1) How have advances in digital representation since 1990 changed professional architectural practice and education? 2) Does the use of digital representation influence the skills most valued in these two communities? If so, how? 3) What effect does digital technology use have on perceptions of student capabilities as they enter the profession? 4) How can contemporary education better integrate digital representation to prepare students for professional practice?

Viewed through the lens of sociocultural learning theory, the research indicates that ongoing support and structure for technological design instruction that meets the developing identities and changing goals of students in context is essential. Explicit instruction in the use of digital representation in the design process will help them to reconcile the value of technology within design as they move from novice learners to more developed user roles in studio environments, and then to office work environments. Since roles will continue to evolve due to community context and tools, educators must be mindful of the impact of changes in professional practice on student motivation. A brief recap of these changes follows.

Recap of Findings

The results reveal four specific findings in relation to the research questions: 1) Negotiation of meaning in the communities of professional practice and education has changed due to the use of digital representation; 2) Motivation for identity formation and trajectories in education have been influenced by digital representation use in professional practice; 3) Perception of valued skills is misaligned between the two communities; and 4) Participation and membership in professional practice have adapted to accommodate incoming identities and the needs of the industry.

Finding 1: Negotiation of meaning in the communities of professional practice and education has changed due to the use of digital representation. The two communities use digital representation for different ends. Professionals use digital representation as a tool to mediate meaning in design, utilizing it in process for reflection and analysis. Inexperienced students without instruction in digital representation for process use finished images as evidence of their design thinking, and to communicate and visualize their ideas for themselves and for others.

Finding 2: Motivation for identity formation and trajectories in education has been influenced by digital representation use in professional practice. The importance placed on the use and skills of digital representation have influenced students to choose to develop skills of digital representation and to consider them more valuable than do professional practitioners. Although professional practice values design thinking and creative process the highest, students have misinterpreted the use of photorealism and representation in practice, believing that these skills are most necessary to gaining membership in firms. While entry may be granted due to the typology of pairing, lasting membership belongs to individuals who are able to participate in activities beyond those that require technological expertise.

In addition, the use of digital representation has displaced drafting and documentation skills needed in construction drawings, as well as the use of sketching in general. Many interviewees documented the use of sketching for communication as a highly valued skill. The diminishing student use of sketching in lieu of digital representation forms identities that do not meet professional expectations.

Finding 3: Perception of valued skills is misaligned between the education and professional practice. The misinterpretation of valued skills between the two communities has contributed to development and emphasis by students on digital skills that may not hold similar value in professionals' view. Students do not always exemplify the skills that professionals state to be valued, leading to the perception that students are not learning the fundamental skills such as sketching, orthographic representation, and document communication. Yet, professional practice welcomes and utilizes the technology skills that new graduates can bring.

Finding 4: Participation and membership in professional practice have adapted to accommodate incoming identities and the needs of the industry. Due to the high technology demands that have grown in the architectural industry with programs such as BIM, firms have adapted team structures to combine the resources of knowledge and materiality expertise of senior architects with the technology expertise of junior architects. The pairing of these "novice/experts" allows firms to leverage all types of knowledge, and in some cases to have the two groups serve as mentors to each other.

Limitations

There are both strengths and limitations to be addressed in the methods used for this study. A major strength contributes to my analysis of the results, and three limitations should be noted in the methods.

The limitations in the methodology pertain to the case study location and sample sizes. The case study was conducted with a single class of twenty-eight undergraduates students over the course of ten weeks. The identity trajectories of these students are likely in very early stages, shaped more by expectations of preparation for graduate study and learning for future practice rather than immediate entry into the profession. Only three surveys were conducted, and the students themselves were not individually interviewed. The short duration of time and experiences of only one class are not necessarily generalizable to other students in other schools and countries. While the setting cannot by nature exemplify all students in all undergraduate architecture programs but only the experiences of the students in the single setting, many of the responses did match research results found in the literature review.

The interviews were conducted with fourteen individuals, with varying backgrounds, technology expertise, years of experience, and positions within their respective companies in the Pacific Northwest. While there were clear themes that emerged from the interviews, a larger sample would certainly have shown if the themes could be considered consistent throughout typical architecture firms located in different cities around the United States. In addition, the limitations of a single interview with each individual did not allow me to verify if the expressed opinions were consistent over time or if they might be specific to that particular time and setting. Observations in each office may have revealed further information regarding staff roles, firm practices, and effects of the use of digital representation in conjunction with each office's characteristic design process and client base.

My experience and familiarity with the setting and communities can be considered both a limitation and strength. My positioning as both an educator and professional who has practiced design enabled me to ask questions that were both pertinent to the research and relevant to both the communities of education and professional practice; however, this positioning may also have limited my perspective on the emerging themes and which were most important for discussion.

When asking the questions about both education and professional practice, my experiences in both communities allowed me to talk with interviewees with a deep level of understanding of the specific community. Other researches may need to spend long periods of time in a chosen setting in order to acquire comprehensive knowledge of its norms and practices. My understanding of design education provided a background for the questions I asked, as well as a perspective on the issues that can arise with teaching technology in the design process and in the development of faculty expertise in current software. In addition, my own experiences as a professional practicing design and mentoring younger designers gave me first-hand knowledge of the difficulties in training inexperienced graduates.

Implications

In the case study by Groleau et al. (2012), the ongoing redefinition of roles due to technology integration exemplifies the situative changes that both student and professional identities will undergo during the transition from education to real world practice. In order to fully utilize technology within professional practice, the community has begun to redefine the valued skills (Birx, 2005). The technological skills that professional practice desires have evolved over time from the ability to use computers as a simple tool substitution to the requirement that architects integrate the design process with digital technology use (Barrow, 2006; Crotch & Mantho, 2008; Kocaturk, Balbo, Medjdoub, & Veliz, 2012). Building Information Modeling (BIM) is the current technology most sought after in graduating students because users without design knowledge are becoming less practical in the working office as the staffing needs increase at the design stage and decrease at the documentation stage (Birx, 2005). Technology integration is becoming less about realistic visual representation, and more about the ability to form and test design solutions in conjunction with using technology to virtually build a building, facilitating analysis for function, cost, energy efficiency, etc. (Seebohm, 2007).

The practice and roles are changing, forcing change in the identities of current members of that community, as well as in the identities of students (Groleau et al., 2012). Students are increasingly looking to professional practice for values of technology and data manipulation in context (Klinger, 2009; Kocaturk, Balbo, Medjdoub, & Veliz, 2012), and may filter what they choose to learn in order to maintain their selected trajectories into professional practice with identities that may include both creative and technological expertise (Nolen et al., 2011). This multimembership in more than one community of practice will influence the way in which students engage with the values of another (Nolen et al., 2011). Students may choose to align themselves with one set of values (professional) and redefine how they participate in another (educational studio) in order to mediate their identities in both (Nolen et al., 2011). Unless instructors structure studio to motivate students to learn digital representation skills in design context, students can choose to engage in technological approaches solely for their own benefit (Ruegemer & Serrato-Combe, 2008), co-creating the studio community's meaning for each other through negotiation (Nolen & Ward, 2008) and emphasizing the wrong skills.

Future Direction

As the meaning of technological knowledge develops with the community due to BIM and other collaborative processes, questions from both professionals and students will surface about how education is conveying these new meanings and values (Klinger, 2009). Situative theory implies that as each office integrates technology, that community of practice must change to accommodate the new meanings and values associated with the shifting relationships and tools of activity (Nolen, Ward, & Horn, 2011). The implications of these changes in the professional community should inform the practices that education implements for technology integration in order to align student expectations and achievement outcomes. The misalignment between the communities is not new, but the ways in which they will need to be addressed must also evolve. Instruction will need to address the gap that can occur when skills in digital representation and knowledge are not integrated (Ambrose, 2007, 2008; Chiu, 2006). BIM requires knowledge of materiality, and experienced architects use that knowledge to negotiate meaning in digital representation. We cannot give students the digital tools for practice without the meaning. Educators will need to be responsible for preliminary meaning negotiation in the educational studio, scaffolding student use of traditional and digital tools, including explicit instruction in appropriate use, leveraging the benefits of each type, and building classroom norms that are similar to those in professional practice. The importance of abstraction and sketching can be emphasized, and then combined with the process of two-dimensional and three-dimensional thinking first in paper, then in digital model. Ambrose (2010) advocates utilizing views of digital models similar to the process of drawing orthographic projections, allowing students to see the value and intention of designing with these views.

Methods for design evolve from individual to collaborative, and the roles in the architectural community as a whole are being redefined to accommodate that (Birx, 2005). Situative theory looks at this whole system and how the individuals change and must change the practices that occur within it (Nolen et al., 2011). Both professional practice and education will change due to the use of digital representation and its influences; in order to maintain a connection between the interests of these two communities, the individual members with each community will need to work within and without to provide that connection. Boundary trajectories and members become the source of meaning for new practices that may need to be reified in one community to the next, implying that educators will need to find ways to support students in learning for identity formation to best meet the needs of the practice. Instruction should prepare students to take a place in this community, and to apply their knowledge to become central members within it. This will mean diligence in teaching appropriate tool use, clarity in the affordances and constraints of tool types, and incorporation of materiality in learning of digital representation. The evolving use of digital technology in architectural practice necessitates faculty that are as able capable with this technology as are practicing professionals, equipped to help students negotiate meaning with digital representation in the design process.

Further study into the evolving motivations of students throughout their educational careers is needed to better understand the relationship of digital representation to students' developing design processes. As students become more adept with software for digital representation, does their ability to sketch actually become diminished, implying a lack of development in internal visualization? Does their less frequent use of orthographic projections in favor of three-dimensional virtual models hinder the development of the ability to envision three-dimensional spaces as two-dimensional plans and elevations, and vice versa? Angulo et al. (2001) and Cho (2012) touch briefly on the importance of this ability in students' development of design creativity and ability and the possible negative impact that the use of digital representation has had. Questions such as these deserve more in depth research to determine possible implications to the skills and abilities of future students and the practice at large.

Conclusion

This study has uncovered perspectives from which to examine how digital representation influences the way designers think and develop their skills. For those that are wiling to accept the challenges and opportunities that technology and digital tools provide, teaching and training new designers holds promise for the discipline of architecture. Our community as a whole can participate in the negotiation of meaning in our practice if we choose to think reflectively about our practice, value new forms of engagement, and trigger new interpretations of the way we design and think with digital tools.

Participation in the community of architecture involves the negotiation of meaning by all members in the current context. The social contexts in which we learn and work are influenced by the individual actions of all who participate, the tools used in our practices, and the trajectories between them. In order to reconcile the identities that form in each context and in turn lead to the next, we must continue to be mindful of the influences that each community has on the others, ever aware that as we renegotiate what makes architecture meaningful, we also renegotiate our places within it.

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Appendix A. Professional Semi-Structured Interview Protocol

Section 1:

1. Why did the office start using technology?
2. How has technology changed your personal approach to practice?
3. How has it changed the office practice?

Section 2:

1. How do you begin a design?
2. How do you use technology?
3. How do you incorporate technology while designing?
4. How does the office incorporate technology?
5. How does new technology/technique/software/ability come into the office?
6. How should students prepare for professional practice in design?
7. How should someone prepare to use technology in design?

Section 3:

1. Is technology important for design?
2. Why do you use technology?
3. Why does the office use technology? (Job roles/responsibilities, ability, training, position, status)
4. Why do others use technology?
5. Does the design process change when using technology?
6. Does technology aid the design process?
7. Why should students prepare to use technology in design?

Section 4:

What is your background in the use of computing for or in design?

Section 5:

1. How would you approach the design process without technology?
2. How would approach the design with the technology that is available?
3. What do you wish technology could do for/in the design process?
4. Should design without technology be a required skill?

Section 6:

1. How do you use technology collaboratively? In office only, or with other consultants?
2. How does technology affect the team members assigned to a project?
3. Do members of a project team have the same roles/responsibilities for technology use and design?
4. Does every member of a team use technology the same way?
5. Does technological ability determine what roles a team member can take?
6. Can team members change their roles or add responsibilities with technology training
7. How does design experience influence roles/responsibilities?
8. Is design background necessary to use technology in your office? Has this always been the case?

Appendix B. Introductory Survey

After the 300 level studio, how familiar are you with Rhino?

1. What is Rhino?
    a. I opened it, but I went back to sketchup
    b. I have messed with it, got frustrated, and went back to SketchUp
    c. I feel confident; I can make straight and square buildings
    d. I could make some curved and complex shapes
    e. I could make a rubber duck using rhino
    f. Frank Gehry calls me when he gets stumped
    g. Other:

2. How familiar are you with the laser cutter?
    a. What is a laser cutter?
    b. I went to training, but I never used it.
    c. I have used it, but I forgot how.
    d. I have used it, and I could do it again.
    e. I can use the laser cutter

3. How familiar are you creating renderings in Rhino?
    a. Not at all
    b. I have done it before
    c. Comfortable, but I could use a few pointers
    d. I know what I am doing

4. In terms of rendering, how familiar are you with the concept of texture mapping and lighting?
    a. what is a texture map?
    b. I understand the concepts, but can't really do it.
    c. I do some texturing mapping, but usually do post production stuff in Photoshop.
    d. I am confident and comfortable.

Appendix C. Progress Survey

1.What I'm learning in this class will:
   a. Prepare me for professional practice
   b. Give me skills that other students may not have
   c. Help me to do better in my studio classes
   d. Helps me understand how technology can be used in design

2. Now that I know a little bit more I will:
   a. Use technology differently than I did before when I design
   b. Think about the construction as well as the design
   c. Do more testing before assuming a design is complete
   d. Do everything exactly the same

3. I still hope to learn
   a. Ways to use the technology to improve/refine my design
   b. Ways to improve my design during fabrication
   c. How to get better at using the technology
   d. Not much, I know enough now

4. Using technology
   a. Is essential to a creating a good design
   b. Allows me to visualize a design in ways that sketches don't
   c. Is easier than sketching
   d. Is harder than sketching

5. Fabricating a design
   a. Is harder than I anticipated
   b. Is easier than I anticipated
   c. Shows where the digital model has shortcomings
   d. Helps me to see where I can improve the digital model

6. It would be great if
   a. What I learned in this class supported lessons in the studio class
   b. Studio demonstrated how to incorporate using the software from this class
   c. Studio work requirements used what I learned in this class
   d. I could demonstrate what I learned in this class in studio work

Appendix D. Last Day Survey

1. How often did you utilize analog processes when designing your projects for this class? Sketching, study models, etc.…If you do use these processes, at what point in the project do you do so? Please answer in the short answer portion.
   a. Always
   b. Sometimes
   c. Never
   d. Other

2. Why is the class suddenly interested in using flamingo? If you personally are not, please answer so.
   a. See below
   b. I am not interested
   c. Other

3. When designing (for this and other classes) do you:
   a. have concrete ideas in mind and then attempt to build them in the computer.
   b. It depends, see explanation below.
   c. Other.

4. Did these projects teach you anything other than how to use a specific piece of software? If so, what?
   a. Yes
   b. No
   c. Other

5. Will you approach (thinking about) future projects differently as a result of anything you learned in this class? Please explain.
   a. Yes
   b. No
   c. Other

6. Did you see any value in failures? Why or why not?
   a. Yes
   b. No
   c. Other

7. Did you feel encouraged to experiment in this class? Please explain.
   a. Yes
   b. No
   c. Other

8. Was there a point in the quarter where you felt the need to play it safe on your projects? If so, when was it?

a. Yes
b. No
c. Other

9. Do you think the material you learned in this class will help you to use similar software or processes in the future? Why or why not?
   a. Yes
   b. No
   c. Why or why not?

10. Did the form of your cool box project effect your final presentation strategy, or vice versa?
    a. Cool box effected final presentation strategy
    b. Final presentation idea influenced cool box
    c. Each influenced the Other
    d. Please explain

11. What is the relationship between what is being taught in this class vs. what is being taught in other classes? I.e., is there an overlap?
    a. Some overlap
    b. No overlap
    c. All overlap
    d. Please explain

12. Will you use rhino or other software to visualize an idea?
    Please explain.

13. Was there anything else you were hoping to learn in this course? If so, what was it? Recognizing the fact that there is a finite amount of time to present information, what, if anything, do you think should have been left out of the course in order to make room for something else?

14. What is Rhino?
    a. I opened it, but I went back to SketchUp
    b. I have messed with it, got frustrated, and went back to SketchUp
    c. I feel confident, I can make straight and square buildings
    d. I could make some curved and complex shapes
    e. I could make a rubber duck using rhino
    f. Frank Gehry calls me when he gets stumped
    g. Other:

15. How familiar are you with the laser cutter?
    h. What is a laser cutter?
    i. b. I went to training, but I never used it.
    j. I have used it, but I forgot how.
    k. I have used it, and I could do it again.

l. I can use the laser cutter

16. How familiar are you creating renderings in Rhino?
    m. Not at all
    n. I have done it before
    o. Comfortable, but I could use a few pointers
    p. I know what I am doing

17. In terms of rendering, how familiar are you with the concept of texture mapping and lighting?
    q. What is a texture map?
    r. I understand the concepts, but can't really do it.
    s. I do some texturing mapping, but usually do post production stuff in Photoshop.
    t. I am confident and comfortable.

18. Do you have any final comments?

Appendix E. Code List and Definitions

Table D.1. *Code list, definitions, and examples of each.*

Code	Definition / Explanation	Examples
First - Level Codes (Descriptive)		
Design Process	Description or reference to steps needed to determine a solution to a problem; includes decision making, comprehension, note taking	Looking for people to solve the problem, a design sense.
		...give me a section of what that meant, diagraming, how did you get there. [Show] the full range of the project development.
		It's so complex, where people should spend more time sketching using trace, and relying on those skills, and actually thinking out about creating the design with different models, and then actually going into the model and creating it form scratch. And we see a lot of people struggling with that because SketchUp was such an easy intuitive tool to go from you know a thought directly to the digital media. But there's that additional stuff when you need to think it out , sketch it out, figure out how it's going to go together before you step into Revit.
Visualize	Imagining or internally considering the solution or creation	I think one of the most interesting things about this transition is the way that you think about buildings.
Thinking	Cognitive consideration of the design process or problem solving	...on the desks, that was interesting things that showed you what people were thinking.

Problem Solving	Process of exploring various solutions to a design question - "satisficing"	It gets to the point where it takes you away from the task at hand. Which is how is this building going together, how does the space feel, are the proportions right, is that mullion slender or heavy, you don't get to think about that, you're so worried about the software trying to interpret your intent. You forget what your intent looks like. I2: I think that's an even bigger problem these days with Revit, and users not sketching out and trying to solve the problem ahead of time before using the software. I mean how much time do we waste on Revit, it seems like it takes an immense amount of time trying to get stuff in there.
		I1: There were a few things you could probably do. So that to me is more of a design thinking approach in how windows relate to walls, And that's maybe about having a sense of the things you want to manipulate and explore in the design process, thinking of a room or a building form.
Reflection	Reviewing or reconsidering a problem solution and considering revisions for improvement	
Analyze	Review existing problem parameters for requirements, restrictions, revelation	But we use a lot of those statistically based programs for analysis.
Creativity	Unusual or unexpected ideas or thinking	
Abstraction	Representation of an object or idea in a manner that is not concrete or identified with a specific item	R: I think that's the beauty of sketching was, just three lines and it already tells you something about the space without having to finish it. I: Exactly.
Collaboration	Working with others for task or problem solution, often leveraging combined knowledge and resources	Or if you're talking to a client, you're talking to a team member, you know, if you're drawing on a piece of paper in front of people and working through the idea, anyone can pick up that pencil, or pen, and start drawing with you, and say what about this.

Representation	A symbol in 2D or 3D, analogue or digital, intended to communicate an idea. Audience could be self or others.	it will help you communicate, envision stuff, look at different situations, and it might instigate certain lines of thinking.
Rendering	Representation of object through virtual means; related to visualization, but externalized; focus is surfaces	But clients today, are looking for, they just don't want a nice idea, they want to see it, they want to walk through it, they want to fly through it, and they want it tomorrow.
Modeling	Process of representation of object, either digital or physical; involves manipulation of objects; distinction exists between digital and physical modeling; focus is solids	R: You have to look at it in 3 dimensions. Whether that's a model or a virtual model. But - physical model building is still something that's really quite used here? I: Absolutely. It's critical to our design process. Because, you know, we use a lot of process models here. So, in the great thing about an actual physical model, versus the computer model, anyone can pick it up, and turn it round. And everyone together can look at it, around at the same time. Again, communication is so key to our process here.
Drafting	Physical process of using a tool to create symbolic representation through documentation; traditionally presented as two dimensional paper documents	we're still in this mode where we draw, and it's well thought out, then you send it to the fabricator, and he draws it, then you make sure his drawings match yours.
Fabrication	Physical creation of object; creation of object at full scale	I: I would say that right now we're on that cusp of the 3D, model, and that digi [R: digifab? I: yep, 3d printer technology, maybe even getting one, and then I'm personally very interested with one of my colleagues with exploring the idea of direct fabrication. Because there's, I think that's the future. That's gonna, when you look at the Barcley Center and you see what they were able to do, that they couldn't do otherwise, it's really exciting.

<table>
<tr><th colspan="3">Second - Level Codes (Analytic)</th></tr>
<tr><td rowspan="2">Change in practice</td><td rowspan="2">Adaptation or adjustment in established or familiar "doing" in a specific context - methods, routines, processes, etc. (Wenger, 1998, p.43)</td><td>Design process – varies per project Seeing it go from diazo to now, the design process has not changed, just how we interact with the technologies.</td></tr>
<tr><td>Yeah, yeah, you don't' think about it. But I think that's a little bit in design. Some people generate ideas while they're in the software. Other people have to think then they get someone to input. But not everybody works that way.</td></tr>
<tr><td rowspan="2">Change in visualization - external</td><td rowspan="2">Adaptation or different means of imagining or considering design and possible solutions through representation</td><td>I: We're tending to work off the models. Which is that's where my concern is. In fact, had a conversation last week with one of our really senior designers, umm, he's over sixty, and he's an amazing craftsman. He was basically saying, we don't do physical models, here. We do it all in the computer and we're losing that - and I don't mean a presentation model, like that one out there - I mean the little maquettes and little studies that a lot of us are used to from, from our early years,
[R: just see what the massing looks like.
I: Yeah, and then you can look at it, and now we do that same thing, we look at it on the computer.</td></tr>
<tr><td>I think the jump from hand drawing to AutoCAD was easier than this jump from AutoCAD to BIM, because, you know, hand drawing and AutoCAD were basically two dimensional depictions of the same thing. Whereas, there's a switch in how you work, When going form 2D to 3D. Which is really strange, because, you know, architecture, by nature, is a three dimensional field. And we're taught to distill it down to or dumb it down, or translate it to a two dimensional field. And now we're getting rid of that kind of translation now.</td></tr>
</table>

Change in thinking	Adaptation, adjustment, or different approach to internal consideration of design	I think one of the most interesting thing about this transition is the way that you think about buildings and the training of your architects will be indefinable in a while - we were trained to think in sections and details, it was a different way of developing a project- more incremental in the growth – to look at it as a model, then responsible for doing this. Instead of 2D , it is imagining it as a model, rather than in section and in parts. I think its going to change the industry in the way that buildings are conceived.
		Thinking is very important, because now I think we've accepted the fact that they think using technology rather than using a pencil or a pen and sketching.
		I: And that's the part, I'm not sure what we're losing. And we may be, fifteen years ago, I would have said, absolutely, if you're gonna hire somebody, they have to be able to draw, they have to be able to communicate by hand. Umm, it's totally wrong if they would design in AutoCAD at that time. With SketchUp, there's been a bridge. Although , I haven't learned SketchUp, and just from looking at it, it's still not that direct connector, the brain to the hand. R: There's an extra step. How will I make that, do that. I: Umm, but the result of what I've seen come from people, I'm a believer that it can be done different ways. Umm, I worry what we're losing.

Tool use - change in selection of appropriate	In architecture, a physical object or objects used in the process of creating a representation for external visualization. This could include writing implements (pen, pencil, paper, etc.) or technological objects that create representations, typically through human manipulation.	I: I think, there's… a really good example is, we recently had an early design concept, that we, in the old days would've just done hand drawings very quick kinda just to get the feel for what would fit on the site, and um, in today's technology we typically use SketchUp. Which is very loose, and, and you can go pretty quickly and get some data from it. And the team made a decision sort of separately to use Revit, which is a more robust system, but less kind of loose and facile. So they used that, and it was a disaster. Because they were getting so specific so quickly, and their whole idea was well, we'll have a really good data base here, that then when we change things, it'll be if we add units, or delete them it will all just kinda automatically update. But, in that expediency they lost sight of what we were really doing, which is trying to come up with a really cool idea. R: Start at the beginning. I: Yeah. And I had a, you know, pretty direct conversation with the team, about why are we using Revit versus SketchUp, and they, they came around, they realized that wasn't the appropriate technology to use, for that.
		I think, you know if you become too dependent on the tool for your process, then that tells you something about your process. Process should be - it might be more efficient using a computer, it might be more efficient using pencil or a pen or a model, but you know. The process itself should be more independent of that. I mean, you should be able to design in your head. You're just giving physical form and enabling process.

		It took a long time for the firm to become comfortable with ultra realistic renderings. [When representation is] Too realistic upfront, [it's] too dangerous –process we go through, same thing with cad, hand drawings had to be done early in the project, because clients would be scared because it was "done" and they weren't done making decisions yet.
		I think that's what it is, we're trying to do exactly that. When we sit down and start project, we talk out loud, about what tools are we going to use, for what purpose, for what milestone. I can't tell you how many times, someone got it in Revit, we're early SD, pushing all bathroom stalls eight hundred 267 different ways, laying out the toilet rooms. I don't need to know where all the toilet partitions are right now. We'll get to it.
		What is Rhino? What should we use it for?
Meaning/value of representation methods - negotiation	The use and importance of tools within the context of professional practice or student learning. Importance of tools and actions is constantly being redefined through the participation of the individuals in each context. As tools and their uses change, the meaning does also. (Wenger, 1998)	I'm realizing the value and quickness of things that I thought would take too long. It's kind of amazing what you can do with it when you are really good.
		So, you know, now, these people, they can draw, but it's not worth anything anymore. What are we gonna do with this hand drawing. We need in Revit. And so we're facing, that transition.

		I1: I wonder if people making models with their files are getting a better sense of the relationship of the model and the physical thing? If they ever built your model. Are you getting R: Would you get the sense, because of the physical sense of creating. I1: Is your understanding full and complete. I2: I don't know, I mean, I think its' definitely a draw back to use the laser cutter to develop the model, because you're spending so much time to create he cut paths, and not focusing on more of the design, understanding the relationships of how it goes together, you're more concerned about developing the design in AutoCAD and making it construable via the laser cutter. So.
		What we're going to do, we're going to build one fairly small project and create renderings with it, then we are going to take that and make physical objects. Hopefully by the end of class you will be able to use Rhino to inform your design and use it for your work
		We are probably going to make something simple like this in the fabrication, something to hold your iPod or something. Can you see the martini glass, the representation and the fabrication?

Roles - membership /identity	Competence in the currently valued tools and practices affords particular levels of participation and status in the context of professional practice (Wenger, 1998).	I: I would have team people do that. I have seen that especially with senior designers, working with younger staff, saying, hey why don't' you do this - and they're standing there in the corner - and I cringe every time I see that. R: Would you prefer that each team member is able to do what they need to do in the software? I: I think that's ideal. I think it's kind of unrealistic. Especially for a lot of older staff. Senior, staff. But still, the idea, I would rather have them, rather than having them say pull here, pull there, and standing behind the corner, you know, I would rather like the communication occur, if they can't do it by computer, do it by hand. And then, it gives the staff member a little bit more ownership of the process, rather than just being a simple drafting …
Pairing - membership / identity	An emerging typology that combines the novice architect/technology expert with a expert architect/technology novice in order to allow both participation within the evolving design and documentation practice prompted by the growing negotiated importance of digital information representation in architecture and construction.	You know, on building projects, and even on planning projects, if they know SketchUp, that's a great entree, because there's a lot of need for SketchUp. And then what the trick is for that person to be a contributing member on the team, doing SketchUp, which can sometime be months of, just basically, rendering, and drawing things that somebody else is directing. [R: production. I: Kind of production level design, yeah. And not to get pigeonholed into that. And we've had just a series of people who are two, three years out of school, that have been that role, and they get to jump around a bit, from project to project, because we have a lot of early stuff that we're studying, or we have a study over here or a study over there, and they have the SketchUp skills, they can be really contributing to the project.

Desired skills - identity	Skills or abilities sought in graduates by professional practice. These may influence the level of membership that entering individuals in the context, facilitating or hindering full membership.	I2: I would say yeah, technology is just another tool. If you don't know how to process, or use another tool to solve the problem, then there's an issue there. You're' just relying on one tool then you become specialized, and you're not really a generalist anymore. I think of this firm, we prefer those types of people that are generalists, that are a board band of skills.
		I: it really does help. And it's starting to become pretty standard, that even those people have great ideas, who have great minds, there's enough of them out there that when we're interviewing, they have that ability and they have the technology behind them. And it's like, we don't have to make a compromise. R.: That would be ideal. I: Yeah, but we're seeing a lot of that. So it's interesting. It's evolving to the point , where a student coming out of UW, WSU, UO, really should have the technology piece. The one that is over here. Understand that technical ability so that they can be a contributor. I think that is important. The other part is, the model making piece. Using those software to be able to construct models, The tactile, building a model, and that kind of stuff, I don't see the connector, that I do between sketching, but I do see once it's built, the ability to look at it in a different way than on the screen.
		R: Other than technology, what skills do you value? I: Looking for people to solve the problem, a design sense. Good presentation skills, abilities, a wide range of skills – full gamut – this person can actually draw. You want a depth in their work, so we can put them on any task that we would need to. Hand drawings, building models, computer models – careers (strong) people should be as agile as possible. We will also bring them up to speed in the anything we need to. We don't have formulas in our projects. We know who ever we have, and their specific skills to complement.

Missing skills - identity	Skills or abilities valued and desired by professional practice but not fully evidenced by graduates.	I agree with D---- or whoever, that the kids coming out of school, they can learn software in a day. They don't know how a building goes together. We can find people who know Revit, who know how to lay out sheets, sections but they don't really know what they're doing yet, so that's part of the internship, mentorship process.
		How much do I need to draw, and to what level of detail, and at some point do I just need to extract it, and draw it in 2D. That's the other thing, you don't need to model every single condition, probably just need to draw it.
Change in practice - Documentation issues	A representation problem caused by new tool use for expected and traditional documentation output that forces modifications to an existing process.	Yeah, I found that redlines was kind of hard because you're looking at in progress 2D plots that didn't' have all the background stuff turned off, or wrongly missing that, so you're just thinking, is that missing, is that a mistake, does that person know that's not supposed to be there. All I can respond to is what's here. And we have to have kind of a little conversation so the red marking isn't as good as, and maybe that has caused us to change how we work through the finalization of documentation.
Materiality	Awareness and/or understanding of material properties and the impact of these characteristics on design and construction methods and decisions.	But the actual ability to jump in and start working in Revit, and in Revit at least as a contributor, Revit you have to know how it goes together, or you have to have someone telling you how it goes together.
Tech skills	Skills related to technology use, specifically expertise with software for design communication.	But Revit and SketchUp, having the technical ability to work in those is important.