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Preparing Future Data Visualization Designers for Professional Practice

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Abstract

As the professional field of data visualization grows, so does the importance of preparing students effectively for the demands of real-world practice. Computing education has historically sought to teach and evaluate abstract knowledge (e.g., theories, principles, guidelines, design patterns) and the application of such knowledge to given problems. However, situations faced in professional practice are often messy, dynamic, and uncertain, and do not lend themselves well to the clear and direct application of such knowledge. This leaves a gap between the knowledge learned in the classroom and what is required for skillful practice in professional settings. In this paper, I discuss some historical reasons for this dominant pedagogical perspective, some of the core features of professional practice that are not typically taught in classrooms, and ways in which data visualization design can be taught to be more resonant with the experience of professional practice.

1 Introduction

Professional roles for data visualization designers have been increasing in recent years. Given the growth of professional opportunities, and the increasing demand for qualified professionals, it is important to consider data visualization pedagogy, and particularly the ways in which we may educate students that align with the realities of professional practice. While increasing attention has been paid in recent years to data visualization pedagogy in a general sense, the relation of pedagogy to professional practice has seen little investigation. The majority of contributions have been focused on classroom activities that instructors try (e.g., [1,10,12,45,62,66]). For instance, some have investigated the use of common pedagogical strategies for teaching data visualization—e.g., active or flipped learning, problem-based learning, and design sprints ([6,19,26,30,49]). Others have focused on the cognitive dimension of learning visualizations [36,63]. While such efforts are promising, and demonstrate a growing interest in data visualization pedagogy, the body of literature is still relatively small—even in relation to other design fields that have developed their own literature on education (e.g., architecture, interaction design, engineering design, instructional design, software development). This is not surprising, as the professional identity of data visualization is still nascent and dynamic. However, recent trends in the profession, such as the formation of the Data Visualization Society and its various initiative and events, suggest some stability may be emerging in the professional landscape. As a result, it is an opportune time to investigate what it means to train students for professional practice as data visualization designers.

In this paper, I articulate the need for more practice-focused pedagogy. I discuss some underlying epistemological factors that have historically been influential in university education, and propose studio pedagogy as a model that may work well for preparing future data visualization practitioners. I suggest several features of studio pedagogy that visualization educators can consider adopting to make their learning experiences more resonant with professional practice.

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1.1 Focusing on Practice

Scholars in several disciplines have noted the importance of training students in ways that are resonant with the complexities of professional practice. This includes not only providing students with the necessary skills and knowledge of the discipline, but also familiarizing them with the tools, demands, constraints, and socio-cultural practices of the workplace. To be successful, this focus on practice resonance must be accompanied by a shift to practice-focused research efforts that help researchers and educators better understand the nature of practice in their discipline. This shift has been taking place slowly in the broader HCI literature over the past couple decades. Two decades ago, in their seminal work on Technology as Experience, McCarthy and Wright [33] argued that the turn to practice came about due to the effects that rationalism had on thinking about technology—in essence, making the study of technology "the study of idealizations of technology." When we deal with abstractions only—and do not investigate how well they align with professional practice—we risk idealizing more than just technology. For instance, Roedl and Stolterman [51] demonstrated how authors of CHI papers commonly reference 'designers' and 'design processes' in overly generic ways that have no clear anchoring in real-world design practice. Dourish [18] has also drawn attention to the "process/practice dichotomy", noting how processes are often formal, abstract, and codified, yet abstracted from the lived experience of the work that gets done. Practices, as contrasted with processes, are the ways in which things really happen in the world. Unfortunately, we often foreground processes at the expense of truly understanding the nature of practice. This distinction has been discussed widely in the ergonomics and cognitive systems engineering literature for many decades, often under the labels of 'work-as-done' vs. 'work-as-imagined' [29]. We often imagine how work is accomplished, or how practitioners operate, and even write papers as if we know what 'designers' do and what 'design processes' look like. However, without engaging in serious practice-oriented scholarship, we run the risk of dealing with idealized forms rather than something approximating professional practice. While previous data visualization scholarship has advocated for more practice focused perspectives (e.g., [3,5,7,27,37,41,65]), little attention has been given to the role of practice in shaping data visualization pedagogy.

2 The Rationality of Practice

What kinds of knowledge are needed for professional practice? As educators, we presumably want students to act rationally; but, to what vision of rationality do we aspire? There is not only one way to act rationally in the world, yet not all forms of professional competence have been recognized in the epistemological lenses adopted by most academic programs. Stolterman has proposed the concept of rationality resonance [58], suggesting that the way students design should be resonant with the accepted norms, practices, and ways of knowing in the professional world of design. To achieve this resonance, researchers and educators must have an accurate understanding of what professional practice is really like, otherwise there will be a difference between our idea of practice and how it really is [20,24,41,59]. Several scholars who have studied professional practice and the nature of professional knowledge have noted how practitioners often know more than they can tell [2,46,52,60,67]. Despite the emphasis placed on abstract, propositional knowledge in university settings, much of the knowledge practitioners have is essentially intertwined with action in the world. This essential connection of knowledge and action has been described using various labels, including knowing-in-action [52], situated action [60], embodied action [18], tacit knowing [47], and others.

Perhaps most famously in the design literature, Donald Schön built on these ideas and developed a critique of the dominant epistemology in the academy. Schön argued that universities emphasize a form of rationality that he called *technical rationality* [52]. This form of rationality foregrounds abstract, formal, objective knowledge at the expense of more situated and personal forms of knowing. The problem is that this kind of rationality simply does not align well with the realities of professional practice. Practitioners tend to be faced with situations involving uncertainty, changing conditions, workplace constraints, goal and value conflicts, and uniqueness—all characteristics that do not lend themselves well to the direct application of technical knowledge to decomposable problems.

Schön traces the history of this view and describes how it has come to dominate institutions of higher education, and how it in turn shapes our approaches to research and education. A detailed summary of this view is beyond the scope of this paper (see [17, 25] for general discussions, and [42] for a discussion related to data visualization). As an epistemology of practice, technical rationality implies certain things about the nature of knowledge and how it should be taught. It suggests that professional activity consists in instrumental problem solving that achieves 'rigor' by applying scientific theory and technique. If academic research can generate objective knowledge, practitioners can simply apply it to given problems, thus achieving rigor in practice. Technical Rationality suggests that rigorous practice results in the application of general, codified knowledge to the specific situations in which practitioners find themselves. This perspective may sound enticing at first, as it readily solves the problem of professional practice being messy, mysterious, and intuitive (which are all bad words for a paradigm grounded in positivism). The biggest problem with this view is that it simply does not align with how practitioners operate in the world. As researchers and educators, we end up being faced with a dilemma of rigor or relevance.

2.1 The dilemma of rigor or relevance

Schön refers to the situation that we face when it comes to the epistemology of practice as the 'dilemma of rigor or relevance' [52]. The dilemma here is that situations that lend themselves to the application of rigorous, formal methods are often not the ones most relevant to practitioners and others in the world. The problems of most importance to most people tend to be messy, unpredictable, and unique, having no predetermined methods or processes that can be rigorously applied to them. He notes that this dilemma is more acute in some fields of practice than others. In some fields, like operations research, it may be possible to follow highly formal, mathematical methods to optimize possible solution paths and achieve rigor in process outcomes. In most design fields, however, where dichotomies of true/false and right/wrong do not make sense, and optimization is often an unhelpful guide, there may be a high degree of uncertainty and, in principle, an infinite number of outcomes that could satisfy the needs of the design situation [25]. As educators in such fields, we need resist the allure of technical rationality and seek out a more appropriate epistemological foundation on which to ground our teaching efforts.

Aside from the dilemma of rigor or relevance, several design theorists have argued that there are fundamental aspects of design that clearly fall outside of the sphere of technical rationality. One that we will discuss here is the issue of problem framing.

2.2 Design is more than problem solving

One of the problems with the technical rationality view is that it assumes the situation in which practitioners find themselves is one in which they are presented with a problem and simply need to solve it. In a design sense, technical rationality implies that practice is about the process of solving a problem, which is often described as selecting the best path from a set of possible ones—e.g., commonly referred to as searching through a 'design space'. However, as Schön and others have pointed out, professional practice has *as much to do with finding the problem as it does with solving it*. In the real world, practitioners are often in situations where the 'problem' itself is not known, or its nature is very difficult to ascertain, and thus there is no clear design or solution space to traverse. There are no obvious problems that can be decomposed, solved, and built back up again. Rather, the designer must engage in a process that has been referred to as problem framing or problem setting—in other words, determining what they are dealing with, what is important and what is not among the range of things being considered, what the scope or boundaries of concern are, and what the consequences of any particular course of action may be.

To complicate matters further, problem framing is not a singular act, but is something that is negotiated and revised over a series of movements and reflections. Most professional roles require designers to deal with open, networked, dynamic, and complex problems [16, 39]. Such problems are rooted in a landscape full of potential constraints and paradoxes, where the solution for one problem is likely to lead to additional problems (i.e., Rittel and Webber's "no stopping" rule [50]). The importance of problem framing is thoroughly documented across many design disciplines (e.g., [16]), as is the inability of technical rationality to explain the competence with which practitioners engage in such work. Design scholars have noted how practitioners are able to rely on design knowledge and design judgment to handle such paradoxes, and in particular make use of framing judgments [13, 32, 53]. This form of judgment becomes key in these situations by providing a new way of looking at the problem situation itself in ways that privilege or foreground certain constraints or aspects of the overall design situation—involving the needs of other stakeholders, the conflicting values or appreciative systems of these stakeholders, and early formulations of potential design solutions [14, 15, 52].

3 Finding Practice Resonance with Studio Pedagogy

The challenge of creating learning experiences that effectively bridge theory and practice is widely known [57]. One typical aim of educators focused on training students for professional practice is achieving authenticity in the learning environment—in other words, making the learning environment approximate the realities of professional practice to the highest extent possible [55]. There are several obvious challenges to doing so, including overcoming constraints on time, budgets, materials, and other resources that influence the nature of professional practice. Although fully replicating a professional practice environment in the classroom is not possible, there are several things that can be done to make the experience more resonant with professional practice settings. In a major review on authenticity in educational settings, Nachtigall et al. [38] suggest that authentic learning includes several key characteristics: collaboration on complex and ill-structured real-world problems; self-directed inquiry and investigation; working with practitioners or experts, in a real-world or professional setting; and using materials and tools that are typically also used by practitioners.

The pedagogical model that has received most attention in design is the 'studio' model. Over the past several decades, several prominent design scholars have proposed that studio pedagogy may be best suited for preparing students for professional design practice [54]. Studio education has sometimes been conceptualized as a 'bridge' between the worlds of student life and professional life [9].

While studio pedagogy has received increasing attention in emergent design fields like user experience design [64], it has not yet become regularly discussed in the visualization literature. Although data visualization educators are surely employing various strategies to make their learning environments more authentic, more awareness of the studio model may be beneficial and may lead to new ideas. Several of the more recent design disciplines (e.g., instructional design, interaction design) have adopted studio pedagogies, although there is a wide variety of practices and characteristics being referred to as 'studio' across these disciplines [22]. Whether visualization educators explicitly identify as employing a 'studio' model is not so important, as long as the useful practices developed over many decades of studio-based education end up influencing the learning experiences in data visualization programs. Here I outline some key characteristics of studio education that could be adopted in data visualization curricula.

Although several conceptual and theoretical characteristics of studio education make it distinct, it often has distinct physical characteristics as well. For instance, a design studio is typically a place where students have work areas that are available to them at all or most times through the school term. This very practically enables students to leave materials in the space and have a consistent place to work. Additionally, and at least as importantly, it creates a space in which disciplinary enculturation can occur, where students can interact both formally and informally in ways that mirror communities of practice in the world [31]. Studio classes typically meet for longer durations than traditional lectures or labs—often multiple times a week for 3–4 hours at a time. Studios generally do not have formal lectures, as they are not seen as being particularly effective pedagogical tools. Rather, in the studio, professors are viewed as more of a coach than a lecturer transferring knowledge. In this setting, students learn by doing, and the coaches provide demonstrations, critiques, and just-in-time instruction as means of formative feedback. Students' work in the studio should take on certain elements of professional practice—e.g., working in teams, dealing with uncertainty and ambiguity, and engaging in peer critique and other collaborative activities. Rather than lectures, quizzes, and exams, students are typically provided with project briefs that contain ambiguous, ill-defined problems that students must tackle through their design work. In the studio, students engage with the complexity and messiness of design, typically relying more on trial-and-error and just-in-time learning than repetition and reinforcement towards the correct application of abstract principles.

The goal of studio pedagogy is to prepare students to handle the complexity, uncertainty, and messiness of real-world practice. This strategy is often in opposition to those that attempt to provide students with prescriptive procedures to follow or abstract theory to apply. Investigations of data visualization practitioners suggest they do not regularly follow abstract models and procedures, and instead rely on more situated forms of knowing and decision making [7,41,43]. Thus, creating similar opportunities in the classroom may be beneficial. While more detailed description of studio pedagogy is beyond the scope of this paper (see [8, 9, 11, 23, 48, 64] for more depth on studio-based pedagogy in different design disciplines), here we suggest some characteristics that could be adopted in most data visualization curricula.

3.1 Open-ended, ambiguous design prompts

While traditional problem solving exercises certainly have value in the classroom, they provide opportunities for experiencing only narrow aspects of professional practice. Such exercises can work well for providing practice on technical problems, but do not give students the necessary mental practice in grappling with problem frames—in other words, engaging in the difficult and necessary work that happens before any technical problems can be tacked. Exercises where students need to practice applying color scales, mapping data onto different visual channels, or create different chart types from a dataset are all valuable—but they provide opportunities only for developing technical skill and for applying technical knowledge to instrumental problems.

Instructors may attempt to achieve practice resonance by providing design briefs for team projects in which the outcome is not specified. However, if they problem is already framed for the students, they are still not getting opportunities to develop the important skills of problem framing. One solution is to deliberately provide prompts in which the problem is not formulated, and the space contains tradeoffs and other complexities that make problem setting challenging. For instance, students can be given a context, such as the quantified self movement, and be given a goal to help users develop better habits and behaviors, through visualizations of their personal data, that ultimately make users healthier and better informed about themselves. This is a notoriously difficult problem—dealing with mental models, personal tracking, and behavior change—where any proposed solutions can easily lead to new problems (see Rittel and Webber's "no stopping" rule [50]). Here there are very well known challenges and tradeoffs underlying the problem, yet students will likely focus on the surface features of the problem and not recognize the underlying challenges.

Providing students with design briefs of this nature forces them to engage in the important acts of problem framing. Because no problem is given to them to simply solve, they are forced to foreground certain aspects of the problem space, attend to them, set the scope of attention, and make critical judgments [43, 44] to help them manage the complexity of the situation. Following a studio model, instructors and peers should engage in regular critique of the students' work, forcing them to more deeply engage with their problem frames and underlying assumptions. This cycle may happen several times, even over a period of a few weeks, providing plenty of opportunity for students to at least partially realize the depth of complexity of such a problem. In following such a model, the focus expands beyond just technical application (e.g., can the student create a good color scale or choose a useful chart type) to recognizing how challenging it is to engage users in meaningful behavior change through data visualization. After all, the ultimate aim of data visualization is to influence our users—whether behavior, understanding, enjoyment, or otherwise—not just to create technically effective visual representations.

3.2 Reflection as a way of being

One of the most significant findings from the study of competent practitioners is that they continually engage in reflection as both a punctuated act and a way of being [52]. Too often our educational environments encourage students to master technical skill without developing a reflective practice in relation to that skill. Students may learn how to regurgitate and apply models, processes, and laws, yet they do not develop the higher-order cognitive abilities of evaluating, modifying, and questioning such knowledge, especially as it relates to its relevance in complex, real-world situations. Schön was a strong proponent of reflection as an attitude and way of being, as being essential to the practice and identity of design [52].

Instructors can engage students in multiple forms of reflection to accustom them to being reflective in their practice. For instance, students can write weekly reflections in a shared space (e.g., Slack, Google Docs), write personal reflections as part of their project work, and engage in live, in-the-moment reflections as part of class discussions and critique sessions. For example, if students engage in a short classroom activity where they need to select a chart type for a dataset, they instructors can have them reflect together in small groups, then share out to the class. Such an act is small in scope, but the ultimate goal is for reflection to become a habitual practice that is performed automatically. By developing habits of reflective practice, students can better understand their level of professional competence and where they may have opportunities for future growth. In a studio setting, it is easier to develop these habits, as students are continually engaging in both formal and information discussions and activities rather than listening to lectures or completing labs.

3.3 Forms of evaluation

As educators, we should consider whether we are disseminating and evaluating knowledge that is essentially disconnected from the learner (as would be expected within the paradigm of technical rationality). For instance, are we concerned with propositional knowledge that can be articulated explicitly on a test or exam? Or, are we evaluating how a student navigates the complexity of a design problem, and how they think and demonstrate knowing-in-action. These two perspectives can look drastically different in terms of assessment. Which of these is more resonant with professional data visualization practice? What kinds of knowledge do data visualization practitioners rely on, and how might they be assessed in a classroom setting? More practice-focused research is needed to adequately answer such questions in a data visualization context, but we can look to more established design disciplines for guidance.

Classic studio education relies on the 'design jury' as one of its central rituals and the primary mode of formal feedback and assessment [4, 55]. The jury is typically made up of more experienced members of the profession (e.g., professors, practitioners), and its primary pedagogical value lies in its ability to provide constructive feedback to students. In a jury review, a student typically presents their work, explaining the process and outcomes along with rationale and an overall design argument. Jury members critique the work, asking questions and probing into decisions that were made. This back-and-forth dialogue offers an opportunity to understand the attitudes and thinking of students—particularly in relation to the dynamic and situated challenges of design work—that exams and even project reports cannot provide very easily. The exact format of the design jury is perhaps not as important as the general intention of engaging students in forms of assessment that move away from recall of abstract knowledge only.

Although mostly beyond the scope of this article, it is important to draw attention to the common practice of conflating evaluation and feedback in higher education. Although evaluation and feedback are both central to modern learning experiences, they should have separate functions. Evaluation tends to be certification-oriented, whereas feedback aims to influence students' future work and learning strategies [68]. Evaluation, including grades, should be more summative and evaluative (i.e., backward-looking, focusing on achievement in relation to standards), and feedback should be more formative (i.e., forward-looking, focusing on growth and future achievement). Not only are these often conflated, but they can become conflicting, in that assessment can *inhibit* the goals of feedback [68]. Historically, in design education, evaluation is intentionally de-emphasized, and feedback is foregrounded in comparison. In such settings, the primary mode of feedback is the 'critique' [28], which often takes on multiple levels of type and formality [40].

3.4 Critique as formative feedback

As part of a reflective practice, designers need to be engaged in critique—both of their work and the work of others. Critique is central to reflective practice, as it is the act of critique that helps refine problem frames and design judgments [28]. Ideally, critique should be modelled to students by instructors as a form of coaching in the studio (cf., design coaching [34, 61]). Instructors can also provide such feedback to students in a range of forms, spanning levels of formality (from an informal 'desk critique' to a more formal final presentation), modalities (discussion, Slack critique, written documentation comments), and combinations of participants (instructor interacting with one or more students). In a studio environment, critiques can range from impromptu to schedules, and dealing with big topics to little ones. For instance, as students work in the studio, the instructor can move around and provide 'desk critiques'—information conversations about what a student is currently working on. The instructor may probe into the choice of a particular visual channel being used, or the selection and cleaning of a dataset. Students can also be encouraged to engage in forms of both formal and information peer critique (see [21]). After some time, the practices of critique and reflection become more habitual, and more intertwined with one another. As students become more critical and reflective, providing rationale and a compelling design argumentation for their work will become second nature. Furthermore, as critique and reflection become more comfortable, students will develop stronger problem framing abilities, as framing requires deep reflection on the nature of the problem to be solved.

4 Moving towards practice resonance in data visualization pedagogy

Although the studio model is preferred by most design disciplines, characteristics of authentic learning can be achieved through several different pedagogical approaches, including problem- and project-based learning, flipped classrooms, and other forms of active or student-centered pedagogy [56]. As more active and learner-centered pedagogies have increased in popularity in recent years, many data visualization educators are likely already employing them in the classroom (e.g., see [1, 6, 10, 12, 19, 26, 30, 45, 49, 62, 66] for examples). However, as noted by Shaffer [55], the epistemological commitments underlying pedagogical approaches are typically hidden from view, yet they strongly determine how the more observable features of learning experiences unfold. If data visualization as a field has been strongly dominated by positivist views on knowledge (see [35, 41]), it is important for educators to examine such underlying epistemological commitments and their effects on educational experiences. Reflecting on such commitments—and their eventual influence on classroom practices and curricular design—is one initial step that data visualization educators can take to improve the practice resonance of learning experiences.

Asking what kinds of knowledge practitioners need to be effective in professional settings (which requires more practice-focused research initiatives); aiming to strengthen the development of such knowledge through curricular activities (which requires awareness of the various pedagogies and disciplinary traditions in the broader design landscape); examining which feedback and evaluation methods are best suited to the learning experiences being envisioned (which requires awareness of the complementary yet distinct nature of evaluation and feedback, and the various modes of feedback that have been successful in other disciplines) are all important steps educators can take—if not in moving towards more resonant learning experiences, then at least in taking stock of current practices and identifying plans for future pedagogical initiatives.

There are, of course, several practical challenges in implementing studio-based education, especially in disciplinary settings unfamiliar with such a model. There may be scaling issues—e.g., how can design coaching, peer and instructor critique, and detailed jury reviews be implemented when course enrollments are high? What if there is no buy-in from administrators or other faculty in the department? Studio teaching often requires much more hands-on engagement both in and out of the classroom, which may be de-emphasized in certain research-intensive environments. Furthermore, students themselves may be opposed to such a model, especially if the course is not highly relevant to their future professional goals (e.g., they want to be software developers and are taking a visualization class as an elective). All of these are common and legitimate concerns. While it may be difficult or impossible to employ a true studio model in some settings, it is probable that one or many of the key features of studio education can be adopted. Combining at least some of the essential features of open, ill-structured problems that require engaging deeply with problem frames; hands-on, active, collaborative, studio work time; a dedicated physical space where the studio culture can thrive both in and out of the classroom; the separation of evaluation and feedback; the primacy of both peer and instructor critique as a formative tool; the focus on knowing-in-action rather than abstract, de-contextualized knowing; and the habitual practice of reflection in its various forms; can move the pedagogical approach beyond merely 'active' learning to something that more strongly resonates with the nature of professional data visualization design practice.

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