High tech invention: Examining the relationship between idea generation and technology in the document design process

Abstract

This article proposes a more complex consideration of the idea-generation stage of the document design process. Survey data collected from multiple sections of graphic design and technical communication classes show that design software and other technology can help students generate solutions to design problems by enabling them to realize design options that they may not have known exist and to adopt a bricolage approach to design that facilitates the process. The author makes several recommendations for how instructors can negotiate the sketching—software divide in their classrooms to ensure that the invention process is optimized for all students.

Keywords

Invention, idea generation, design, software, technology, bricolage, sketching, process, document design

In designing and writing content, authors' interactions with technology may involve deciding what software they will use to produce the content and over what platforms they will design the content to be delivered. Authors may not otherwise consider technology, certainly not in a way that would influence how they brainstorm ideas and develop solutions to solve the design problem at hand. Imbuing technology with any sort of agency in the early stages of the process may feel contrary to an author's notion of what it means to compose creative, rhetorically savvy content.

With regard to composing visual texts, the prevailing assumption among professional and technical communication (PTC) theorists has been that invention and idea generation are more creative and productive when removed from the influence of technology. Specifically, theorists have suggested that both visual thinking and the visual composition of documents may be improved if technology use is minimized, especially in the early stages (Brumberger, 2007; Kostelnick, 2013). As Brumberger explained, minimizing the presence of technology allows students to work through visual problems and seek creative solutions using "the tools of their minds and their hands before they rely on the tools offered by the computer" (p. 396). Kostelnick proposed a low-tech pedagogical approach to design, especially in the idea-generation stages. He asserted that using technology can prevent students (especially novice learners) from learning how to design rhetorically by "getting them to settle on a design too quickly because of its ease and immediacy" (p. 267) rather than choosing it because of its rhetorical persuasiveness. He argued that technology has the potential to "sabotage student learning by truncating the invention process and curbing the student's inclination to think creatively and flexibly about design solutions" (p. 266).

As PTC instruction has become more serious about designing (not just writing) content, it is important to examine not only the process of design but how technical communicators can best engage with that process at each stage and how instructors can best guide the role that technology can play throughout the process. In this article, I focus my discussion on the relationship between technology and the idea-generation—or invention—process in design. I discuss the limited existing research that has been done in this area and present the results of a study that surveyed 159 students in seven sections of technical communication and graphic design courses over eighteen months, asking these students to report on their design process and their use of technology throughout that process. The results paint a much more complex picture than what Brumberger and Kostelnick suggested, showing that software and other technology, for some students, can enable them to realize design options that they may not have known exist and to adopt a bricoleur approach to design that facilitates the design process.

Existing Research

Until recently, sketching has been taught as the exclusive mode of idea generation in design fields. But research supporting the importance of sketching has often relied on theoretical

and anecdotal perspectives from experienced designers (e.g., Lawson, 2002) rather than a large scale, empirical examination of the relationship between students and the software or other technology they use to produce their designs. Observations from experienced designers and design instructors can provide valuable insight; however, the scholarship seems to agree that more empirical research is needed. Research is more common in design fields such as architecture and engineering because of the popular use of CAD (computer-aided-design) software, which has been employed in those fields since the early 1990s (Lawson, 2002). In architecture and engineering, the use of CAD is now ubiquitous, influencing both the design process and the pedagogical approaches to design (Robertson & Radcliffe, 2009). The research in those fields seems to have progressed from a desire to keep CAD out of the idea-generation process entirely to the desire to figure out how CAD software can be better designed to help facilitate that process. Architecture and engineering fields differ substantially from graphic design and technical communication fields because the former design 3-D spaces and objects and the latter design 2-D messages. But the architecture and engineering fields provide interesting findings that can inform how we can think about using design software in PTC.

A study of expert architects (Bilda, Gero, & Purcell, 2006) found no difference in the quality of their designs (based on evaluations of design outcome, cognitive activity, and idea links) when the architects were asked to use sketching in the idea-generation stage versus when they were asked to rely solely on mental visualization during that stage. Although this study looks at expert architects, it is relevant because of the role that mental visualization may be able to play for novice designers, as I discuss later.

Studies that examine the effect of sketching for novice designers generally characterize *novices* as mid-level design students rather than those who have no design or sketching experience. One study that does include true novices was conducted by Verstijnen and Hennessey (1998), who devised a number of 3-D and 2-D cognitive tasks typical of the idea-generation stage and compared the results of these tasks as they were completed by two groups: experienced (i.e., upper division) engineering students and novice (i.e., with no expected sketching or design experience) first-year psychology students. The researchers found that sketching improved the ability of the engineering students on the 3-D restructuring and combining tasks. But sketching was actually more detrimental than helpful for these students on the 2-D task: "The fact that sketching can even deteriorate performance, as was the case in the 2D task, suggests that being compelled to sketch in conditions where it is not necessary will only distract the subject" (p. 535). This finding complicates the assumption that sketching is always preferable to other options for idea generation. It is also significant because PTC design work is almost exclusively 2-D.

Most significant, Verstijnen and Hennessey (1998) found that sketching was not as helpful for the novice students as it was for the engineering students overall. They suggested that "differences in drawing skills may explain the novices' inability to use

sketches for restructuring. Expert and novice sketches differ sufficiently in appearance to warrant this conclusion" (p. 537). Verstijnen and Hennessey concluded that "only expert sketchers benefit from externalization of images" (p. 539). This finding is especially relevant because, as the results of my study will confirm, PTC students typically do not arrive in our classes with strong sketching ability, so compelling them to sketch as the only appropriate means of idea generation regardless of their ability to do so may not benefit them in their design attempts.

Even a skeptic of using CAD in the early design stages, such as Lawson (1997), dean of Architectural Studies at the University of Sheffield, U.K, admitted that the results of two experiments by Robert Aish, in which non-designers used software to design spaces that were then judged to be more effective than those designed by experts, suggested that "the creative imagination of non-designers could be unleashed by CAD, which effectively de-skilled the drawing process and certain simple evaluative procedures, so that designers could express and explore ideas that their own drawing skills could not support" (Lawson, 2002, p. 329). Those results suggest, then, that students' drawing ability may not be able to fully realize their ideas the way that software might.

In a more recent study of idea generation and CAD, Veisz, Namouz, and Summers (2012) followed the work of four senior engineering students across a semester-long capstone course in order to monitor their use of CAD software throughout the design process. Veisz et al. also interviewed engineering novices and experienced practitioners and academics to better compare the novice students' practices with and perceptions of CAD with those of professionals in industry and academia. The researchers concluded that CAD software is a positive force in designing for engineers and architects but that the potential remains, especially for novice designers who tend to use CAD to a greater extent in the idea-generation stage, of falling prey to what Robertson, Walther, and Radcliffe (2007) called *circumscribed thinking*, *premature fixation*, and *bounded ideation*. *Circumscribed thinking* occurs when the software tool limits what the designer would like to produce, *premature fixation* occurs when the designer becomes resistant to change as the design takes on a high level of complexity or detail, and *bounded ideation* occurs when the ease with which the software can be used decreases a designer's motivation to find the best possible solution. Robertson et al. recommended that to help prevent these concerns from occurring, instructors must make students fully aware of the potential for them to occur.

My purpose in this study is not to refute the effectiveness of sketching as an idea-generation method for some students—or the possibility that circumscribed thinking, premature fixation, and bounded ideation will occur when students use software in the idea generation stage. Rather, I intend to paint a more complex picture of the role of software and technology in the invention stages of the design process and show that, in spite of the concerns, there are also advantages to using software and other technological resources that can help students generate ideas and solutions.

Software and Invention: A Pilot Study

I first discovered a more complex picture of the relationship between technology and idea generation in a small study I conducted in a visual communication class for technical communication majors. As part of an invention exercise to help students become more comfortable thinking visually, I asked students to visually depict a sound using either hand drawing, software, or a combination of both. The activity was never intended for revision or formal production, and students did not see each other's work. The results showed that there was no difference in the kinds of visual expression exhibited by students who had hand drawn and colored the assignment versus those who had used software (or a combination of both) to generate their solutions to the assignment; in fact, there was a remarkable similarity between designs across type (see Lauer, 2013b).

The study I report here is a follow-up to that initial study but it is much more extensive in its scope. In this study, I use 18 months of quantitative and qualitative survey data collected from multiple sections of upper division graphic design and technical communication classes to show that our assumptions about technology in the early design stages are overly simplistic and that the composing process for individual students can be effective both with and without the use of technology. The results show that while some students preferred sketching, especially graphic design students, who are actively encouraged and taught to sketch from the beginning of their program, many technical communication students reported that software better facilitates their idea-generation process. Technical communication students who use software in the idea-generation stages are often able to mimic the thoroughness of a hand-sketched process, be playful in their invention practices, adopt a bricolage or sampling approach to their creative process, and broaden their design options.

Study Design

To evaluate the influence of software on the idea-generation (invention) activities of technical communicators, I surveyed 18 months of graphic design[1] (GRA 361, n = 81) and technical communication (TWC 411, n = 78) classes. I was granted Institutional Review Board approval for this study. I chose to administer a series of surveys to both graphic design and technical communication classes because I wanted to compare the results of the technical communication students, who typically do not have much experience with either software or hand drawing, with those of graphic design students, who typically have much greater experience in both areas. Graphic design students are taught from their initial enrollment in the major to value sketching as part of the idea-generation process. One of the graphic design professors involved in the study described the importance of sketching to designers:

> Designers think, shape, and transform their ideas while they doodle, sketch, and draw. They are mediums to brainstorm, visually investigate, and

> problem solve with least effort and minimum time. The acquisition of these skills is intrinsic in the [Graphic Design] Program. The undergraduate and graduate curriculum introduces appropriate tools that facilitate doodling, sketching, and drawing at all levels of study. Irrespective of the subject matter of the class they may be in, instructors expect students to maintain a sketchbook where in they record their thinking, investigating, and problem solving process. The academicians and professionals alike encourage, value, and reward the routine and consistent practice of these skills (M. Patel, personal communication, November 28, 2012).

This perspective is in line with experienced designers' arguments about the importance of sketching (Veisz, Namouz, & Summers, 2012), as well as with Brumberger (2007) and Kostelnick (2013).

I used purposeful sampling in my decision to survey the particular technical communication and graphic design courses in this study. Although these courses happen to be offered at my university (one of which I also taught), I deliberately chose the courses because of their subject matter, assignment types, design emphasis, upper division status, and relevance to PTC. As such, my sampling was convenient but also purposeful, and my familiarity with the courses and programs had the added advantage of facilitating my access to the study participants. This familiarity also enabled me to control variables that were important to my ability to collect and analyze meaningful data, such as consistent course content and access to software.

Koerber and McMichael (2008) argued that convenience sampling is widely used in technical communication and enables researchers to collect rich data because of the close relationship between researcher and research site. But convenience sampling suggests a sample based on ready availability over ideal suitability, so researchers must avoid overgeneralizing the results. Although purposeful sampling suggests a more deliberate recruitment of participants based on certain qualities or traits, this method can fall prey to a lack of diversity within the parameters of the research questions or, worse, the recruitment of participants based on the result that researcher is hoping to achieve. I attempted to avoid these limitations in this study by designing a data collection period that would extend across several different semesters of the same course taught by a variety of instructors (but using a standardized curriculum to control for variables). I further address the potential bias of my study sample later in this article by disclosing my assumptions about the kinds of data my study participants were likely to provide and the questions that remained in light of those assumptions.

Because my study sampling was purposeful, the courses I included in the study were chosen for their appropriateness to the study question. The TWC 411 course (5 sections surveyed from January 2011-May 2012) is the only required visual communication course in the technical communication major. This course introduces visual communication principles such as contrast, hierarchy, alignment, grouping, consistency, and others, as well

as considerations of images, typography, layout, and color. Students in all sections of the course were required to produce a logo, poster, and brochure. The GRA 361 course (2 sections surveyed from August 2010-December 2011) is a third-year course required of all graphic design majors. It emphasizes information design and assignments that include informational graphics, instructions, product design, and posters. I chose this particular course because the coursework most closely resembles the kind of visual work completed in technical communication.

Survey Administration

I administered a series of surveys to each course section (see Figure 1). Within the first day or so of each course section (in both TWC 411 and GRA 361), I administered an introductory survey (See Appendix A) that asked students to rate their experience level with a variety of software programs and design tasks. For the TWC 411 students, I then administered three additional surveys, each one after students submitted the final draft of each major assignment (logo, poster, brochure; see Appendix B for the logo survey). Because the GRA 361 course was structured without individual assignment due dates but instead evaluated students at the midterm (when about half the assignments were supposed to be completed) and the final (when the other half would be completed), I administered two surveys to those sections (in addition to the introductory survey), one at the midterm asking about three of the assignments and the other at the final, asking about two additional assignments. The surveys asked students to:

1. indicate the extent to which they used "sketching, drawing, modeling, or other non-software (e.g., non-Adobe CS) activities to work through the various stages" of a project, using a scale of 1 to 10, with 1 equaling *not at all* and 10 equaling *exclusively*.
2. indicate the extent to which they used "design software (e.g., Adobe CS) to work through the various stages" of a project, using a scale of 1 to 10, with 1 equaling *not at all* and 10 equaling *exclusively*.
3. estimate the overall hours they spent on a project.
4. estimate the number of hours they spent on each stage of a project.
5. provide an extended written reflection "to better clarify the relationship [they] had with both sketching/drawing and design software as [they] worked through the [project name] process." They did not need to "reference the stages above, but were free to write about [their] use of drawing or software throughout the design process in any way [they] wish[ed]" but they needed to "describe why [they] chose to use drawing or software at various times in [their] process and what [they] felt [those choices] did to facilitate [their] ideas, conceptions, translations, revisions, and production."

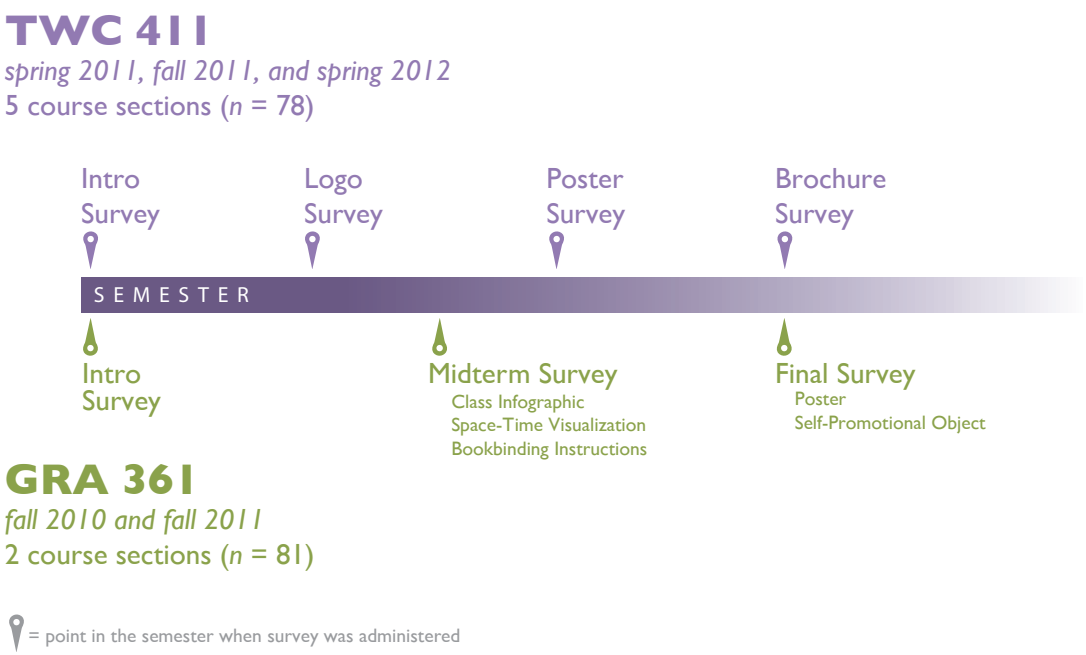

Figure 1. The survey administration process throughout the semester for both GRA and TWC classes.

The survey questions reference the "stages of design" that were listed and defined for students within the body of the survey. There are arguably many stages of design, but in order to use language that would be understood by all the study participants, I focused on four stages in particular:

- *Conceptualization*, process of formulating an idea or thought. This is the stage when designers begin to construct plausible solutions based on their research.
- *Translation*, the development of graphic visual illustrations and designs.
- *Revision*, literally to see again, to look at something from a fresh, critical perspective. It is an ongoing process of rethinking the design: reconsidering arguments, reviewing evidence, refining purpose, and reorganizing or reconceiving the presentation.
- *Production*, the process of final output with the help of hardware and software.

Assignments

For the GRA 361 sections (fall 2010 and fall 2011) I asked about five assignments, three in the midterm survey and two in the final survey. In fall 2010, 37 students participated, with 100% completing the midterm survey and 78% completing the final survey. In fall 2011, 44 students participated, with 100% completing the midterm survey and 86% completing the

final survey. Instructors were the same for both sections. The fundamentals of the assignments were also the same though the assignments used different data sets. For instance, both the fall 2010 and the fall 2011 sections completed a class survey and infographic, a space—time graphic, bookbinding instructions, a poster, and a self-representation object. But in fall 2010, the assignment for the space—time graphic asked students to illustrate the BP Oil Spill while in fall 2011 this assignment asked students to illustrate the Wallow Fire.

For the TWC 411 sections (spring 2011, fall 2011, and spring 2012), I asked about the three major assignments in the course—a logo, poster, and brochure—in a survey that I administered immediately after students submitted the final draft of each assignment. Three different instructors (five sections) taught TWC 411 during the study period, all of whom agreed to let me survey their students. I was one of the instructors, and students in my classes accounted for 20 out of the 78 TWC students (26%) who participated in the study. Of these 78 students, 96% completed both the logo and poster survey, and 90% completed the brochure survey. Although the course was taught by three instructors, the course readings, structure, and assignments were deliberately consistent across all sections. Additionally, a one-way analysis of variance (ANOVA) revealed no differences at a $p = .05$ level between instructors and the study variables, including the results from the introductory survey, total hours spent on each project, and the extent to which students used sketching versus software in the four stages of the design process for each of the three projects (Appendix C).

Software

One of the most important controls for this study was consistent access to design software across all students who participated in the study. All TWC students had unlimited access to Adobe CS programs on and off campus by logging into the University's remote server using their university login ID and password. All GRA students were required to have laptops and access to Adobe CS products on those laptops. In this way, access to the software would not affect a student's decision about using the software throughout the design process.

No formal attention to software training was provided in the GRA 361 classes because workshop and tutorial resources had been made available to students in the graphic design major previous to this course, and by the time students were enrolled in GRA 361, they were expected to know how to use the software to produce finished designs.

All TWC students were provided a common set of .pdf tutorials and practice files out of *Adobe Illustrator CS4 Classroom in a Book* (2008), available to students for free through the university library's Safari Tech Books Online database. Students were given course credit for completing tutorials throughout the semester. They were also encouraged to find tutorials on the Internet or enroll in Lynda.com video tutorials if they needed additional assistance.

Assumptions and Questions

Because of my experience as a teacher of TWC 411 and my familiarity with the GRA program, I started out the study with several assumptions. I expected that GRA students, who at the time of the study were juniors at the university and had already completed two years of graphic design course work, would report a higher ability with using both hand-sketching and software than would TWC students, who came from a more diverse, general-studies background. I assumed, because of my discussions with GRA faculty about the value of sketching espoused in all courses in the major, that GRA students would employ a great deal of nontechnological sketching in their design process. I also assumed that GRA students would be more experienced with the software and thus more confident in their use of it, resulting in their spending proportionately less time than TWC students would on the final production stage of design. Finally, I assumed that because GRA 361 is considered a "studio" course, in which students spend multiple hours three days a week in a design classroom, the GRA students would report spending more time overall on projects.

Conversely, I assumed that TWC students would report having less experience with both sketching and software because they were not required to have an ability with either of those before enrolling in TWC 411. I also assumed that because TWC students would not come in with a strong background in drawing and because their final drafts would need to be completed using a software program (Illustrator, InDesign, etc.), they would employ software throughout all stages of design and would spend most of their overall project time on the production stage because of their relative inexperience with the software.

In light of those assumptions, I was hoping that my study would answer these questions:

- How would the use of software versus sketching change as the semester progressed?
- How would the use of software versus sketching change as the assignments changed?
- What do the design processes look like for students who primarily sketching versus those who primarily use software in the invention or idea generation stage?
- What does the idea generation process look like for students who do not have experience with either sketching or software?

The last two questions were of particular interest to me because I wanted to see what students who did not arrive in class with any particular comfort level with sketching or software would report. I wanted to make room in the design process for discovering differences that might arise from students' myriad previous experiences (i.e., comfort levels) with drafting and software programs or their lack of training or experience with either sketching or software. I was interested to see not only what students reported about their process, but also how their reports both confirmed and challenged ideas about the design process.

Once I finished collecting the data, I charted in a series of graphs the numerical data that students provided in the survey about the extent to which they had experience with various software programs and the extent they had used sketching and software throughout the design process. Because I asked students in the narrative section of the survey to "better clarify the relationship [they] had with both sketching/drawing and design software as [they] worked through the [assignment] process," I coded these narrative data using the qualitative analysis tool HyperResearch. I developed four codes that I used to categorize the students' attitudes and experiences toward sketching and software in the idea-generation stage: "facilitated by sketching," "facilitated by software," "limited by sketching," and "limited by software." After further reading of the narrative data I developed a fifth code—"using the mind"—which I used to tag instances in which students described visualizing ideas in their minds as a method of idea generation that preceded their use of sketching or software (or was done in lieu of using those tools).

Results and Discussion

In presenting the results of my study, I compare the responses of TWC students with those of GRA students. Although I surveyed TWC students from courses with three different instructors (including myself) using identical curricula, a one-way analysis of variance (ANOVA) revealed no differences ($p = .05$) between the students taught under various instructors and the study variables, including the results from the introductory survey, total hours spent on each project, and the extent to which students used sketching versus technology in the four stages of the design process for each project. First I discuss my finding from the numerical data, and then I discuss my narrative findings.

Numerical Findings

The numerical findings include students' assessments of their introductory sketching and software skills, their ratings of their sketching and software use throughout the design process for each assignment, and their reporting of the time they spent on each stage of each assignment.

Introductory Skills. The introductory survey administered to both GRA 361 and TWC 411 students revealed substantial differences in how students rated their experience level with design activities and software programs. Figure 2 shows a graph comparing students' reported experience levels with sketching, vector illustration software (e.g., Illustrator), image-editing software (e.g., Photoshop), and document design software (e.g., InDesign).

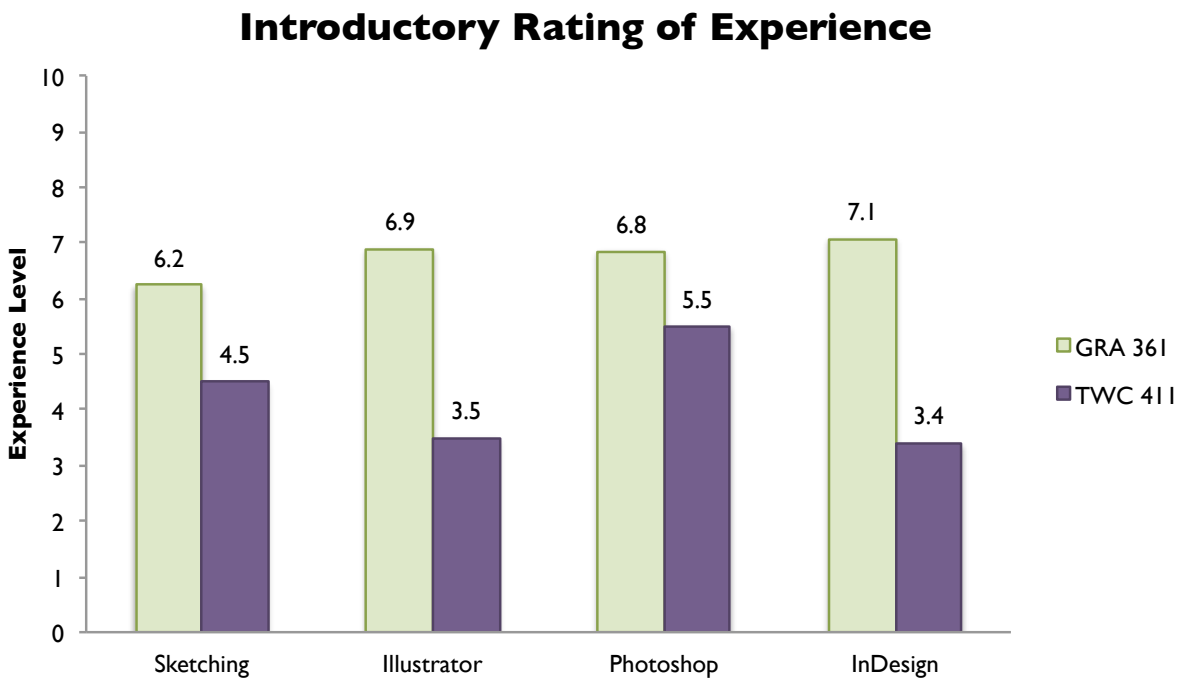

Figure 2. Column graph comparing GRA 361 and TWC 411 students' reported levels of experience with sketching, Illustrator, Photoshop, and InDesign. *Note*. 1 indicates *not at all experienced* and 10 indicates *very experienced*.

Design Process. Both the numerical and the narrative data revealed clear patterns that differentiated the processes of GRA students from those of TWC students and the extent to which students in each group used software versus sketching throughout the design process. As predicted, TWC students used software to a much greater extent throughout all stages of the design process, and the pattern was similar regardless of the assignment type (logo versus poster versus brochure) or point in the semester (logo was the first assignment; brochure was the last assignment). Figure 3 illustrates the sketching versus the software trajectories through the four design stages for each assignment.

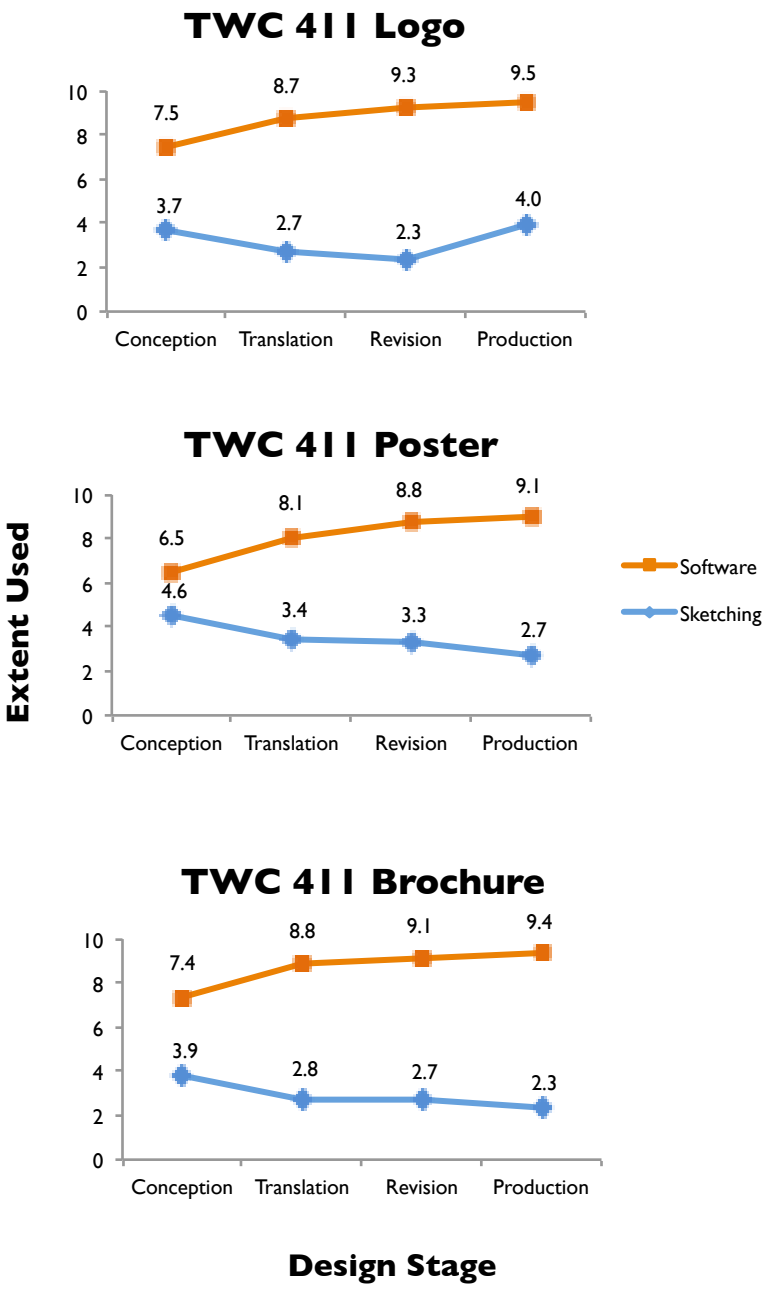

Figure 3. Line graphs comparing the extent to which TWC students reported using sketching versus software throughout the four stages of design to compose a logo, poster, and brochure. *Note*. 1 indicates *not at all* and 10 indicates *exclusively*.

Although every assignment followed a similar sketching-software use pattern, slight variations are interesting to note. For instance, the TWC students reported less extensive use of sketching in the first three stages of the logo compared to the first three stages of the poster and brochure. This is likely because the logo is a smaller, more contained

assignment with greater emphasis on typography, so software may have facilitated students' ability to select and manipulate typefaces. And unlike the poster and the brochure, the logo assignment was more conducive to the inclusion of simple visual elements that could be drawn, so it is also understandable that students would use sketching more in the production stage of that assignment.

Comparatively, GRA students also showed a great deal of consistency in their use of sketching and software throughout the design process although that process followed a different pattern. The line graph for the class-survey infographic shown in Figure 4 represents the trajectory of almost all of the assignments that the GRA students completed for the course, indicating a greater amount of sketching than software use in the idea-generation stage followed by an increasing use of software toward the final production stage.

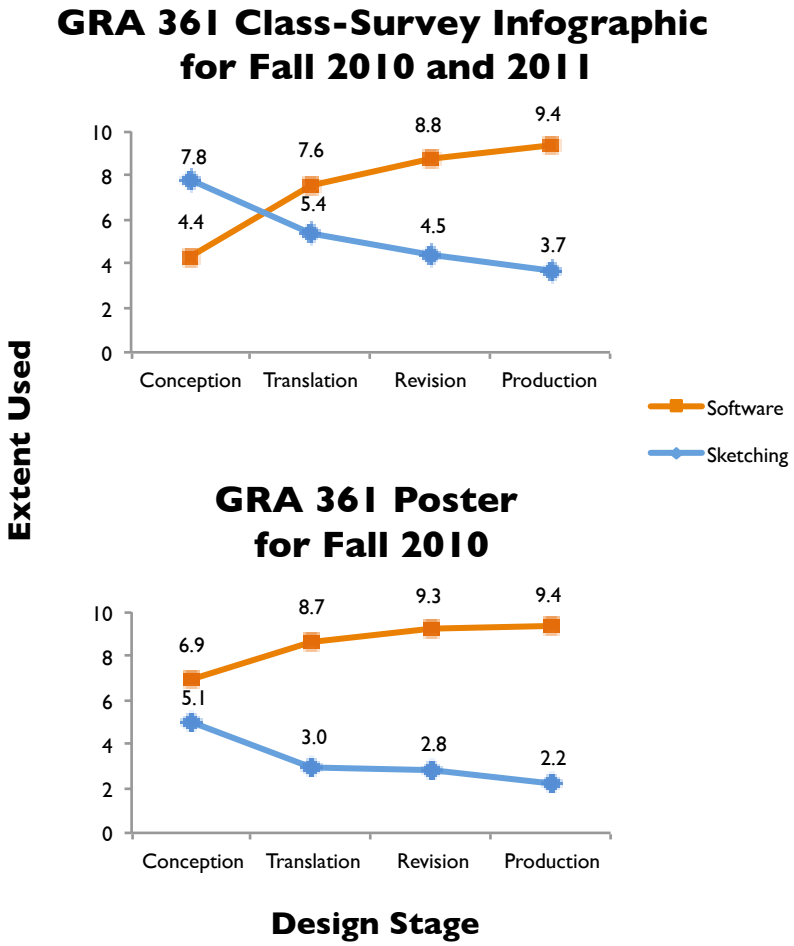

Figure 4. Line graphs comparing the extent to which GRA 361 students reported using sketching versus software throughout the four stages of design to compose a class-survey infographic and a poster that used digital images. *Note*. 1 indicates *not at all* and 10 indicates *exclusively*.

One notable exception to that pattern was the trajectory for the poster assignment completed in the fall 2010 section of the course. This assignment was different from the others in that students were asked to build a poster around a digital image that they had developed in a previous course. Figure 4 also shows the trajectory of sketching versus software for that assignment, which strikingly resembles the trajectories for the TWC assignments shown in Figure 3. Many fall 2010 GRA students commented in their narratives that they used software to a much greater extent in the poster project because the original content was digital. As Alex[1] wrote, "The nature of the assignment lent itself to being sketched almost entirely on the computer. Our images were already on the computer, so conceptualization was simply a matter of importing images to Illustrator." And Brook explained, "Our beginning source was digital, so one would've had to go out of their way, with a desire to make the assignment unnecessarily difficult for themselves in order to do non-digital sketches for this assignment." Although only representative of a single course section, this finding is noteworthy because of the extent to which contemporary professional and technical communication work can comprise preexisting digital elements. This finding is worth paying attention to in future research.

I found no statistically significant correlations, however, between students' experience level with various programs and their use of software versus sketching throughout the design process. This finding appears to be the case with both TWC and GRA students because there was not enough variation in their skills and practices within each group. Most GRA students had high levels of experience with both sketching and software, and most reported using sketching primarily in the idea-generation process. Conversely, most TWC students reported lower levels of experience with both sketching and software, and even though some students reported using sketching, most also reported high levels of software use in the idea-generation process.

Time. The results revealed differences and similarities between the GRA students and the TWC students in the proportion of time they spent in each design stage. Figure 5 shows the average percentage of total project time that each group spent in each of the four stages across all projects. As Figure 5 reveals, GRA students spent more time than TWC students did in the translation stage whereas TWC students spent more time than GRA students did in the production stage.

[1] All names are pseudonyms

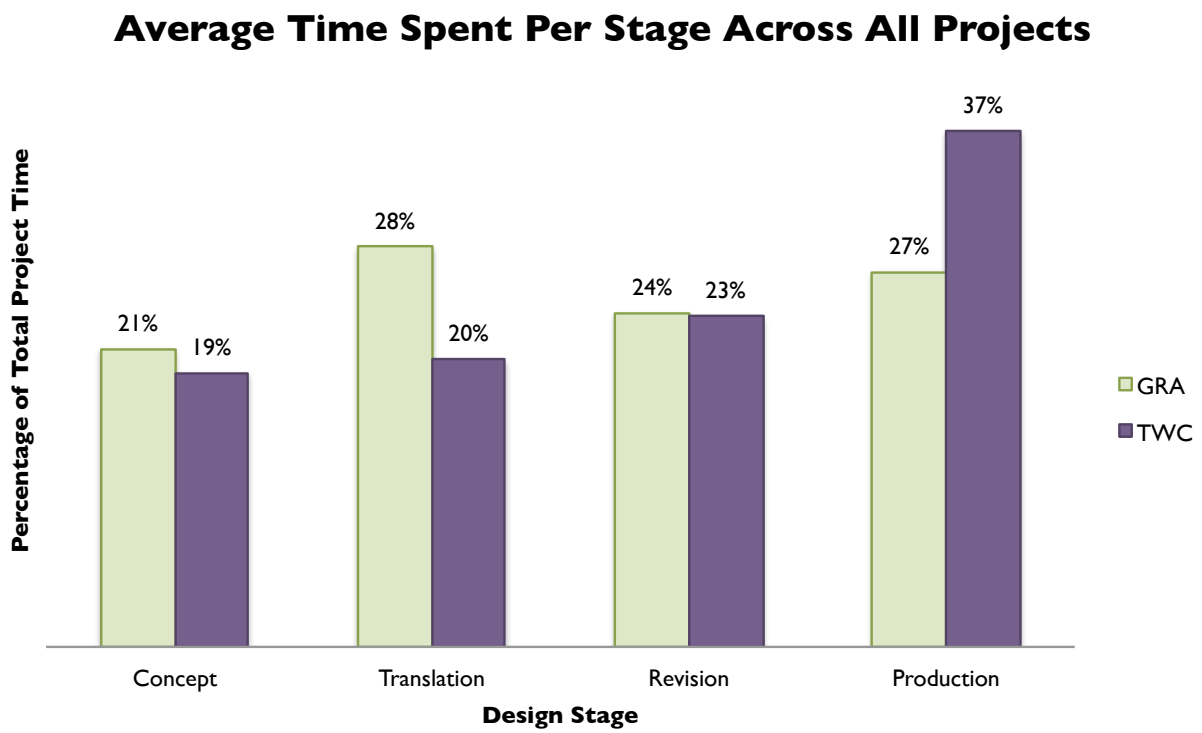

Figure 5. Column graph comparing the average time that GRA 361 and TWC 411 students spent in each design stage across all projects.

It is not surprising that GRA students spent more time in the translation stage because, compared to the TWC students, they reported substantially greater use of sketching in the idea-generation stage, requiring them to translate their sketches digitally during the translation stage. It is also not surprising that TWC students spent more time in the production stage because they did not have as much experience as the GRA students did with the software; thus, it would likely take them longer to realize their ideas as final products. But what I do find noteworthy is that both groups of students spent almost the same proportion of time in the conception stage even though the TWC students were more likely to use software during this stage. This finding seems to contradict the concern of premature fixation—that students spend less time generating ideas when using software as opposed to sketching because software encourages them to commit to a final concept earlier in the idea-generation process.

Narrative Findings

The narrative data students provided as part of the survey provided insight into why students used sketching versus software throughout their design process and how they felt about it. Clear patterns emerged in the narrative responses of each group of students. In line with what the numerical data suggested, almost all graphic design students reported

sketching as their primary method of idea generation followed by using software for revision and production. This finding was true across all assignments, unless the original content was digital (as in the fall 2010 poster assignment). Conversely, the narrative responses of the TWC students were more varied. Some reported sketching on paper, but many reported using the software right away or far earlier in the process than the graphic design students had reported.

In the responses of both groups, students reflected on the extent to which they used software and sketching throughout the design process and how those tools limited or facilitated their processes. The results of my coding of these responses are presented in Figure 6.

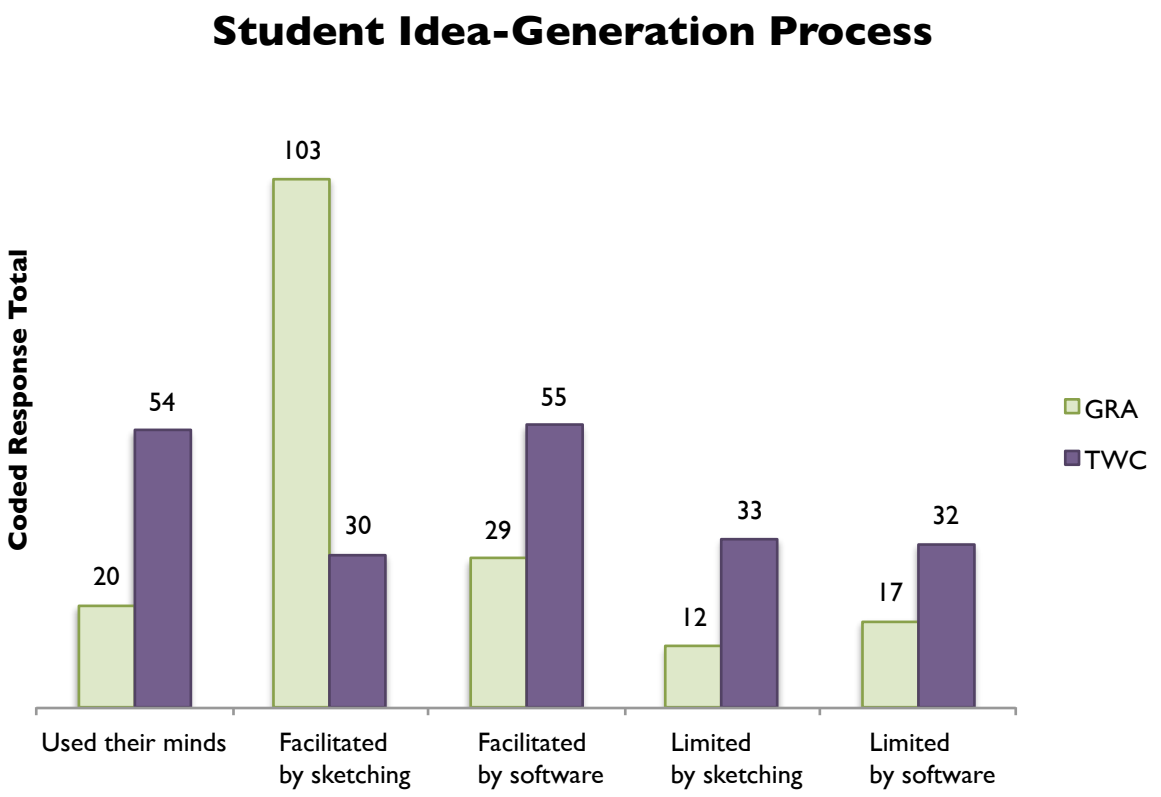

Figure 6. Column graph comparing the number of instances that GRA and TWC students commented on how software and sketching either limited or facilitated their idea-generation process.

Similar to the numerical data, the narrative data showed that the GRA students overwhelmingly used sketching to facilitate their idea-generation process. They discussed sketching as being easier and more efficient, allowing them to come up with more ideas and to record those ideas more quickly. For instance, Chloe shared, "Drawing and sketching is easier for me so I use drawing to produce many sketches of ideas for the project." Nate

commented, “I sketched until I had an idea with direction because it was the most efficient way for me to release all of my ideas and determine their potential.” Audrey related, “I primarily used sketching to get my ideas flowing and to come up with a concept of what I wanted the final piece to look like.” And Emma said, “I did a lot of sketching in my sketchbook because it was faster and more convenient than building all of the ideas from scratch in illustrator.” Such responses support the established field and program philosophy that sketching is the preferred method of idea generation.

The TWC students, conversely, cited software as facilitating their idea-generation process the most, followed by using their minds to generate ideas. Some students did cite sketching as facilitating their process, but there were slightly more instances in which students cited sketching as limiting their process rather than facilitating it. These students provided several reasons for their preference for using software in the idea generation stage, including their personal experience, their perception of their own skills, and their ability to maintain an “organic” process that includes “play.”

Personal Experience. Sarah explained that she “works through the process mentally” and then “heads straight to illustrator”:

> With my job already being in technology . . . I find it really difficult to do things by hand . . . like hand-sketching. The only time I actually will do something like this is: A. when creating web site (as opposed to a single web page). Why? because, storyboarding the site's various paths to each of its pages help[s] to better organize the layout and design of the site. B. When creating JAVA programs. Using the ""if...then"" process helps, again, to organize the various programming steps into a logical process in which the program must be developed.

Sarah’s explanation suggests that she is already familiar enough with technology to feel comfortable using it early on in the process. It also suggests that she understands her process: The amount and type of content determine whether she uses sketching in the earliest stages, not the software.

Perception of Their Own Skills. Many students cited their lack of drawing ability as a reason for not sketching in the early design stages. Jessie was rather emphatic about her difficulty with sketching and her preference for using the computer: “I do everything on my Mac. I suck at freehand and it just ends up taking me longer. THE MAC FREES ME FROM MY ARTISTIC LIMITS. Thank God.” John admitted that he uses software exclusively because “I am pretty terrible at sketching even the littlest of things.” Oliver provided more detailed reasoning in his comments:

> I find using Illustrator from the beginning is easier than putting my ideas down on paper. The image is cleaner, easier to organize, and I can create several different versions without being distracted by my previous attempts

> (what I mean is, I can save and close a file and start over new and "fresh"). Once I was happy with one of my ideas, I then edited and revised it several times within Illustrator. Again, using a digital medium like Adobe Illustrator really helped during the revision process. Using one of the tools called layers, editing the logo became simple as I was allowed to move and edit certain parts of the image around, without affecting other parts of the logo. If I made a mistake, or didn't like how one layer looked, I simply hit a few keys and the image was fixed to a previous stage. In addition to layers, changing/picking the color was very easy to do, not to mention the color range that I'm able to pick from. These are some things [I] can't do with paper, at least not without a lot of time and effort.

Oliver is discussing not just his perception of his own comfort level with the software but also how the software provides more control, more options, more speed, and a cleaner working and revising environment. Those are some of the same reasons that GRA students cited for preferring sketching.

Ability to Maintain an "Organic" Process That Includes "Play". Kostelnick (2013) suggested that instructors encourage a "low-tech" approach to design, which includes sketching and more natural forms and topics. Although this approach may be effective for some students, several TWC students discussed their idea-generation process as "organic," and as one that included play and sketching even though they indicated working exclusively with software. For instance, Barb reported doing some sketching for the logo assignment, but commented, "I really did not use hand sketching at all for the poster. My process during this project was very organic." Greg reported, "The more I played around with the software the more I wanted to experiment with different design elements and colors. The experimental process played a large role in the evolution of the ideas and ultimately the final product." And Stella explained why she preferred to use software rather than sketching:

> I always chose to use software for all stages of the process. Essentially these software pieces have turned into my sketchpad as the[y] offer me a great range of control that my untrained sketching hand does not have. My imagination can run wild but often gets hung up when I try and visualize it with a sketch.

Stella's account confirms Lawson's (2002) suggestion that software can "unleash" the creative imagination of nondesigners because their imaginations cannot be effectively supported by their novice drawing skills. This point seems especially relevant to technical communication students, who are not typically required to become proficient in drawing and yet will be asked to design documents as part of their larger communication goals.

Using the Mind. Figure 5 also displays the number of instances that students in both groups cited that they used their minds as a method of idea generation. As the first pair of

columns show, TWC students referenced this method more than twice as often in their responses. As Alex remarked, "because I cannot draw by hand . . . I visualized my poster in my mind, and I proceeded to create it in Illustrator." Matt related, "I do not usually 'sketch' or handdraw things. I tend to translate straight from my thoughts to something digital." Catherine shared, "since I am not a very good sketcher I usually work though the whole process mentally and translate everything using the actual program I am using. (i.e. Illustrator)." Jake explained, "I didn't feel that I needed to make a sketch for this poster because I could visualize it much better than I could draw it." And Jen commented, "I did not use any drawing or sketching. I literally closed my eyes and visualized what elements I thought would work for my destination." As these examples reveal, many TWC students used visualizing in their minds in lieu of sketching, sometimes as a result of their limited sketching ability. Such visualizing was not nearly as common for GRA students. This discrepancy between the groups is not surprising considering how experienced GRA students reported being with both sketching and software, which are tools that those students have learned to rely on in their idea-generation process. The role of the mind in the idea-generation process for TWC students, however, seems to reflect what happens when students are not well versed in using either sketching or software.

The idea of conceptualizing ideas in the mind is not entirely new in the literature. Hanna and Barber (2001) studied the attitudes and practices of architecture students who were asked to design a studio space using only CAD tools (i.e., no sketching). The researchers found that students shifted from a sketching to a thinking approach to concept formation and declared that more research needed to be done to "assess the impact of this shift on the quality of design solutions" (p. 278). But Bilda, Gero, & Purcell (2006) found that mental visualization is an equally effective way of generating ideas for expert architects. Although TWC students are not design experts, this finding calls for further research to see if the same trend might be true for novice designers who do not possess the sketching skills that might help them to realize their ideas.

One way of encouraging students to externalize their ideas would be to implement a more regimented sketching program as part of technical communication curriculum; however, technical communication instructors do not typically come from a graphic design or art background and thus may not feel qualified to teach sketching as a technique. Also, implementing a focus on sketching, including providing training toward that end, would require technical communication faculty to make compromises in other areas, which might not be in the best interest of students' overall education. An alternative approach, then, would be to introduce sketching as an option for certain kinds of idea-generation tasks and to introduce software and other technologies for other tasks. This approach may prove effective considering the extent to which TWC students reported that software already facilitates their idea-generation process.

Process. What is most striking in the narrative data of TWC students is the extent to which a

software-mediated process can in fact mimic the assumed thoroughness of sketching. This finding combats the concepts of premature fixation (when a designer resists change as a design becomes more detailed or complex), circumscribed thinking (when a designer feels limited by the constraints of the software), and bounded ideation (when reliance on software decreases a designer's motivation and creativity). These concepts reflect instructors' fear that once students use software and see their designs begin to take shape, they will resist exploring different ideas altogether because they either would not want to start over or would think that their designs looked polished enough to be rhetorically effective when it in fact they might not be.

And yet, the narrative data from the TWC students show that they engage in a thorough process and value that process, as Tom's comments demonstrate:

> I honestly had no idea what I wanted to do with this before I got started. So I grabbed a couple relevant photos, threw them into Illustrator as templates, and just started playing with the Illustrator tools. I ended up throwing away a LOT of that early work but it gave me a few gems that turned into my concept. I generally don't use ANYTHING aside from a sketch pad and a writing tool at the very early creative portion of design because I don't want to spend 40 minutes figuring out a tool and ignoring the creative. I was comfortable enough with Illustrator at this point that it didn't encumber my process at all and actually opened up a couple creative possibilities.

Tom's account contains several important findings: First, Tom started out the process by "playing" and "throwing away a LOT [his emphasis]" of early work. Students who play are willing to challenge their limitations with software and try new things without becoming wedded to early ideas. A process that emphasizes play—via sketching or software—is exactly the kind of process instructors should encourage. Second, Tom is aware of the importance of not "ignoring the creative" in the early process, and that awareness has helped him maintain a thorough invention process whether he is sketching or using software. Finally, for Tom, Illustrator actually "opened up a couple creative possibilities." This finding illustrates a concept that Manovich (2010) called "software thinking" in which the software we use allows us to exceed our own visualization capabilities to provide us with possibilities that may not have been previously available.

Sue, another TWC student, also illustrates the concept of "software thinking" in saying, "As I became more familiar with Illustrator, I gained ideas about the use of color, shapes and curves, lines, and text in my design. Prior to that, *I didn't even know what was possible* [emphasis added]. I had general ideas, but no real clear details." For Sue, the software provided avenues of exploration that expanded her realm of possibilities for the assignment. Limiting Sue to using sketching exclusively during this stage would not likely have provided the same level of expansion.

Besides software thinking, TWC students also adopted the process of a bricoleur to help generate and develop ideas in the early stages and throughout the process. *Bricolage*

is a term that can refer to both an assemblage of diverse elements and a process by which a question is approached and explored. Turkle (1995) used the notion of bricolage to emphasize improvisation and negotiation in the problem-solving process. Turkle described bricolage in terms of "tinkering" and achieving a "soft mastery" of a subject. In her research with programming students at Harvard in the 1980s, she discussed that several of these students had learning styles that seemed contrary to what was considered appropriate in their classes. For example, Lisa enjoyed tinkering with prepackaged programming code and developing her own relationship with programming by writing her own programs. She was discouraged from doing so in her classes, however, and was instead encouraged to adopt a "proper style" and stop playing with code in ways that were "a waste of her time" (p. 54). Turkle described Lisa's style of learning as "soft mastery," a flexible, negotiated, nonhierarchical approach that involves tinkering with a variety of ways of trying things (p. 56).

In an exceptionally thorough account, Emma takes us step-by-step though her bricoleur process for developing a logo for The Oregon District, an arts-and-dining district of the downtown area in her hometown (see Figure 7). Emma's brainstorming via sampling a wide variety of Internet material plays a particularly important role in this process:

1. I first researched what branding existed for my location. I didn't want to do anything that looked like what the Oregon District already had.
2. I then deeply thought about the location; what did I associate with it--what thoughts came to mind, what do I like about it, what do others think about it etc.
3. After pondering [that], I began exploring related ideas, such as Oregon the state, and the Oregon Trail. Also, I found a really cool flickr feed of Dayton/Oregon District around the late 1800s for typeface inspiration. At this point, I was leaning towards making the logo relate to the Oregon District's past.
4. I searched for inspiration on various websites that focus on design & logos e.g. (logopond.com). I'm interested in what independent designers come-up with, rather than focusing on well known/well received logos.
5. At this point, I was just spinning my wheels because I honestly had no idea how to represent something that encapsulated so many different ideas/cultures/business etc. So, I decided against a logo that represented the past, and focused more on the present/future. That being said, I researched other similar areas in Ohio, and I determined that the location was now rather trendy, so the concept of "trendy," which is risky, governed how I wanted the logo to appeal to others.
6. After considering what makes my location what it is, I narrowed it down to a few topics: restaurants, bars, art/crafts, hipsters/scenesters. With the recent changes/revitalization efforts to the Downtown Dayton area,

attempting to attract more families, I decided to align the logo with those on-going efforts.

7. After attempting to make "Oregon" & "District" work with my initial typeface selection, I realized I was heading down the wrong path. So, I cut my losses and chose two fonts that had great contrast, but wouldn't tie the logo to a specific time-period.
8. I then found the vector tree to compliment the logo, which I then modified to include the two ideas I wanted to meld into the logo: cuisine & art.

Figure 7. The Oregon District logo designed for TWC 411.

Emma's account shows just how complex the invention process can be when a student uses the options available through software, image sites, and other Internet design sites. Emma gains inspiration by perusing Flickr feeds of old-time photography and Web sites devoted to independent typography. This kind of inspiratory sampling is a form of bricolage that involves tinkering, or playing around, with many software programs and sampling a variety of content (textures, line and image elements) from different Internet sources in ways that seem to expand the creative process rather than limit it.

Illustrating the importance of bricolage to the creative process, Johnson (2011), related the story of eight high-tech neonatal incubators that were sent to Meulaboh, an Indonesian city, after the 2004 Indian Ocean tsunami. Within years of being sent; however, all eight incubators were out of order due to humidity, power surges, and the inability of the local staff to read the English instruction repair manual. In response, a team of engineers set out to develop an incubator that would be easier to maintain and repair in a developing country, where power and parts were often unreliable. The team discovered that automobiles were a common mechanical item used in developing countries and decided to build an incubator out of car parts (a battery, headlights, and other parts that would be familiar to anyone who has driven and repaired a car) in order to ensure that

inconsistent power supplies would not be a problem and that the local people would be familiar enough with the parts to be able to repair the incubators when they broke. Johnson told this story to illustrate how good ideas are,

> Inevitably, constrained by the parts and skills that surround them. We have a natural tendency to romanticize breakthrough innovations, imagining momentous ideas transcending their surroundings, a gifted mind somehow seeing over the detritus of old ideas and ossified tradition. But ideas are works of bricolage; they're built out of that detritus. We take the ideas we've inherited or that we've stumbled across, and we jigger them together into some new shape. We like to think of our ideas as $40,000 incubators, shipped direct from the factory, but in reality they've been cobbled together with spare parts that happened to be sitting in the garage. (p. 28-29)

That garage, for students inexperienced in the more formal elements of design and drawing, has become the design software and Internet resources that have made editing and cropping images, choosing type and color, and arranging layers of elements on a page more accessible than ever before.

Implications for Classroom Practice

In light of the data I have presented here and my own experience as a teacher of visual communication, I have developed five recommendations for how instructors can negotiate the sketching—software divide in their classrooms to ensure that the invention process is optimized for all students—those who prefer sketching and those who may benefit from using software in the early stages of design.

1. *Make the process visible and show students advantages and disadvantages of sketching/technology*. Introduce students to the stages of design and highlight the idea-generation, or invention, stage as one that deserves special attention. If students invest in this stage, they will save themselves revision time and help ensure that their ideas are more rhetorically effective. To elongate the idea-generation stage, instructors can include sketching exercises (e.g., Kostelnick, 2013) as well as exercises that use software and emphasize the particular affordances (type, color, arrangement) of software. Be sure to introduce students to the ideas of premature fixation, bounded ideation, and circumscribed thinking as real pitfalls of using software without also privileging a thorough design process.
2. *Require students to document their process to ensure that there is one*. In a previous study (Lauer, 2013a), I found that students who were required to account for their rhetorical choices in a written document actually produced stronger designs. When instructors ask students to account for their design process, students are likely to pay greater attention to that process and to the fact that there should be a process. To make sure that students do not give the

invention stage short shrift, we must ask them to engage in invention activities and discuss those activities with their instructors and classmates. Allowing students to use software and other technological sources will support the wide range of skill levels and previous experiences that students typically bring to a technical communication class. Working with that experience rather than against it will likely produce more confident, persistent students.

3. *Experiment with playful visualization activities.* This recommendation has been made by Brumberger (2007), Lauer and Sanchez (2011), and Kostelnick (2013), but it bears repeating because instructors need to set aside class time for "play"—activities that do not directly translate into deliverable documents. Examples of visualization activities include asking students to stretch the limits of the creative imagination by visualizing abstract sounds, smells, and textual elements; manipulating shapes; and cropping and framing image elements. Encouraging such play can help students take some of the stress out of the design process and reveal (to novices especially) the wide range of possibilities that can emerge when there is no pressure to develop a final deliverable. Wilde and Wilde (1991) is just one source that provides a number of such visualization activities.
4. *Encourage and help guide effective sampling and bricolage*. Software and technology would not appear to be such threats to the creative process if we saw them as avenues through which to connect our students and what they already know to ideas and tools that could expand the possibilities of their designs. The work of technical communicators differs from graphic designers in that much of a technical communicator's visual work is assembling image elements, text, color, and typefaces rather than inventing new graphical forms and typefaces. Whereas graphic design students may require whole semesters devoted to typeface design or color theory, such training would be impractical for technical communication students, who need to, above all else, learn how to clearly and appropriately craft messages to suit particular audiences, purposes, and needs in a communicative situation. Technical communicators may take their own photographs or develop their own image elements, but they are equally likely to use existing material, such as stock photography, which they crop, position, and integrate with other elements in a document to construct a design that communicates information effectively. We might practically position our students, then, as bricoleurs—adapting and arranging available visual and textual material in ways that communicate information effectively to specific audiences—and encourage our students to capitalize on the resources of software and the Internet as well as material they have developed on their own.
5. *Require software tutorials and instruction throughout the semester*. The narrative data suggest that for some students, the software they used actually provided

them with ideas that facilitated their creative and rhetorically effective use of type, color, layering, image editing, and other elements. This is a significant advantage that software can provide to technical communication students who do not have a graphic design background. Software training should be required because students will ultimately need to use software to develop a deliverable for a portfolio or client. Training and tutorials should accommodate different skill levels and be awarded class credit to ensure that students complete them. Brumberger, Lauer, and Northcutt (2013) discussed several ways to effectively integrate software and tools training into the classroom. Prioritizing this kind of training is important for several reasons. Being able to generate ideas using software has been shown to facilitate the sharing of those ideas among team members (Robertson, Walther, & Radcliffe, 2007), which is advantageous for group work. Highlighting the ways in which software can improve the design process (i.e., by helping users to manage layers and artboards, move and manipulate image elements, and choose types and colors) can help students visualize solutions in new ways. Pairing software training with clear messages about the circumscribed thinking, premature fixation, and bounded ideation problems that can beset software users is also essential.

Conclusion

While graphic design students overwhelmingly prefer to use sketching as an effective means of idea generation, technical communication prefer to use software and mind visualization rather than sketching to facilitate their idea-generation processes. But if it is largely true that the work of graphic design majors is graphically superior to that of technical writing students, then it would seem to follow that favoring sketching as a way to generate ideas would help technical communication students become more adept designers. But a few factors complicate this assumption. First, just because graphic designers may produce graphically superior work does not necessarily mean that their work is rhetorically superior. This is a comparison that needs testing, but it is difficult to test when the two groups of students operate from such different initial skill levels. Also, graphic design majors are likely attracted to the major because they have previous drawing or graphic experience. After enrolling as freshmen, they take several years of classes focused exclusively on sketching and drawing. Technical communication majors, on the other hand, usually start taking required classes in the major as juniors and in two short years must develop facility in writing, content management, usability, Web authoring, and other increasingly diverse skills. Having to learn such a diversity of skills in a rather short amount of time prevents these students from developing more advanced sketching and graphic skills. Thus, suggesting that technical communication students should sketch in order to ensure stronger visual messages because graphic design students sketch and seem to have greater graphic design skills ignores these other factors.

Additionally, as the instructor of some of the students involved in this study, I was responsible for evaluating the quality of their work while they were in my class. After reading students' reflections on their processes for this study, well after their time in my class was over, I can confirm that many students who reported using software in their idea-generation process were able to produce documents that were as well designed and rhetorically-effective as those of students who began their process by sketching.

Ultimately there is simply too little research that has empirically examined the relationship between technology and the design process. What research has been done has focused on 3-D design fields such as engineering and architecture rather than information and communication design fields such as graphic design and technical communication. More research is needed to determine the kinds of experience levels and assignment types that benefit most from experimenting with technology, the ways in which we can effectively teach software in the classroom, and the attributes of various software programs that can facilitate invention and the creative process as well as those that we should avoid.

As the quantitative and qualitative evidence from this study suggests, it is no longer useful to ask, Does technology help or hinder the invention process? Rather, we should ask, How can we help our students generate effective ideas and execute those ideas well? When we ask that question, we are able to consider what the process of idea generation looks like when we include technology, software, and other ways of composing besides the more traditional sketching.

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Notes

[1] The graphic design major has been recently renamed visual communication design, though all of their courses retain the *GRA* prefix. Because the course title of the TWC course also includes the phrase *visual communication* I will refer to classes in the visual communication major as graphic design classes.

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Autobiographical Note

Claire Lauer is an associate professor in the Technical Communication program at Arizona State University where she teaches courses in visual communication, information design, and research methods. Her research has appeared in *Technical Communication Quarterly, Written Communication, Journal of Business and Technical Communication, Kairos, Computers and Composition, Programmatic Perspectives*, and *Composition Studies.*

Appendix A
Introductory Survey

Design Process Research Survey - Introduction

Exit this survey

3. Introduction and experience

The following questions will ask you about your previous experience with some of the common design activities and software programs used in your visual communication course. If taking this survey after your course has begun, please respond with your experience level as it was BEFORE the start of fall 2011 classes

1. Please indicate your experience level BEFORE ENTERING THIS CLASS with the following design tasks and software programs

	1 (Not at all experienced)	2	3	4	5	6	7	8	9	10 (Very experienced)
Drawing or Drafting	○	○	○	○	○	○	○	○	○	○
Working with mixed media (paint, sculpture, collage, etc.)	○	○	○	○	○	○	○	○	○	○
Constructing/building models or mockups	○	○	○	○	○	○	○	○	○	○
Digitally editing photographs	○	○	○	○	○	○	○	○	○	○
Creating new digital images	○	○	○	○	○	○	○	○	○	○
Adobe Photoshop or similar graphics editing program	○	○	○	○	○	○	○	○	○	○
Adobe Illustrator or similar vector drawing program	○	○	○	○	○	○	○	○	○	○
Adobe InDesign or similar document design program	○	○	○	○	○	○	○	○	○	○
Rhino, 3D Max or similar 3D graphic program	○	○	○	○	○	○	○	○	○	○

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Appendix B
Logo Survey

Design Process Survey - LOGO

Exit this survey

3. Use of both sketching and software technology in the design process

The questions you will be responding to throughout the semester will ask you about the extent to which you used both hand drawing/sketching and design software (e.g., Adobe Illustrator or other programs) throughout the design process when developing the following projects for this class:

- Logo
- Poster
- Brochure

This survey asks you about the **LOGO**. The questions below will reference stages of design, which are listed and defined here.

Stages:

Conceptualization Conceptualization is the process to formulate an idea or thought. This is the stage when you begin to construct plausible solutions based on your research.

Translation In the context of visual communication, translation is your development of graphic visual illustrations and designs.

Revision Revision literally means to "see again," to look at something from a fresh, critical perspective. It is an ongoing process of rethinking the design: reconsidering your arguments, reviewing your evidence, refining your purpose, and reorganizing or reconceiving your presentation.

Production Process of final output with the help hardware and software.

1. This question asks you about your LOGO. Please indicate on the chart below the extent to which you used sketching, drawing, modeling, or other non-software (e.g., non-Adobe CS) activities to work through the various stages of that project

	1 (Not at all)	2	3	4	5	6	7	8	9	10 (exclusively)
Conceptualization	○	○	○	○	○	○	○	○	○	○
Translation	○	○	○	○	○	○	○	○	○	○
Revision	○	○	○	○	○	○	○	○	○	○
Production	○	○	○	○	○	○	○	○	○	○

2. Please indicate on the chart below the extent to which you used design software (e.g., Adobe CS) to work through the various stages of the LOGO.

	1 (Not at all)	2	3	4	5	6	7	8	9	10 (exclusively)
Conceptualization	○	○	○	○	○	○	○	○	○	○
Translation	○	○	○	○	○	○	○	○	○	○
Revision	○	○	○	○	○	○	○	○	○	○
Production	○	○	○	○	○	○	○	○	○	○

3. Please calculate the total number of hours you spent on the entire design process for the LOGO, from coneptualization to production.

[ ]

4. Please input a number in each box below as an estimate of the number of hours you worked throughout each stage of the LOGO

Conceptualization	
Translation	
Revision	
Production	

5. Please provide a written description to better clarify the relationship you had with both sketching/drawing and design software as you worked through the LOGO process. You need not reference the stages above, but are free to write about your use of drawing or software throughout the design process in any way you wish. Please be sure to describe why you chose to use drawing or software at various times in your process and what you felt each did to facilitate your ideas, conceptions, translations, revisions, and production.

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Appendix C

Table Showing One-Way ANOVAs for TWC Class Variables Versus Instructors

		df	*F*	*p*
Introduction Survey	Drawing or Drafting	2	.987	.379
	Adobe Photoshop or similar graphics editing program	2	.951	.392
	Adobe Illustrator or similar vector drawing program	2	1.039	.360
	Adobe InDesign or similar document design program	2	.969	.385
Project Hours	POSTER	2	.711	.495
	LOGO	2	.328	.721
	BROCHURE	2	.600	.552
Extent to which students used **sketching** throughout the LOGO process	Conceptualization	2	1.237	.297
	Translation	2	.122	.885
	Revision	2	.133	.876
	Production	2	.007	.993
Extent to which students used **software** throughout the LOGO process	Conceptualization	2	.198	.821
	Translation	2	.020	.980
	Revision	2	.177	.838
	Production	2	1.110	.336
Extent to which students used **sketching** throughout the POSTER process	Conceptualization	2	.049	.952
	Translation	2	.013	.987
	Revision	2	.248	.781
	Production	2	.263	.770
Extent to which students used **software** throughout the POSTER process	Conceptualization	2	.005	.995
	Translation	2	.424	.656
	Revision	2	.086	.918
	Production	2	.166	.847
Extent to which students used **sketching** throughout the BROCHURE process	Conceptualization	2	1.499	.231
	Translation	2	.238	.789
	Revision	2	.448	.641
	Production	2	.157	.855
Extent to which students used **software** throughout the BROCHURE process	Conceptualization	2	1.455	.241
	Translation	2	.500	.609
	Revision	2	.267	.767
	Production	2	.096	.909