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INVESTIGATING PRIMING EFFECTS OF SKETCH EVALUATION INSTRUCTIONS ON IDEA GENERATION PRODUCTIVITY

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ABSTRACT

Engineering design involves intensive visual-spatial reasoning, and engineers depend upon external representation to develop concepts during idea generation. Previous research has not explored how our visual representation skills influence our idea generation effectiveness. A designer's deficit in sketching skills could create a need for increased focus on the task of visual representation reducing cognitive resources available for the task at hand – generating concept. Further, this effect could be compounded if designers believed that their sketching skill would be evaluated or judged by their peers. This evaluation apprehension could cause additional mental workload distracting from the production of idea generation.

The goal of this study is to investigate and better understand the relationship between designers' sketching skills and idea generation abilities. In this paper, we present preliminary results of the relationship between independent measures of sketching skill and idea generation ability from an entry-level engineering design and graphics course. During data collection, task instructions were given in two ways to independent groups: one group was instructed upfront that sketching would be evaluated, while the second group was kept blind to the sketch evaluation. In this paper, we also examine the potential priming effects of sketch quality evaluation apprehension on idea generation productivity. The results show that sketching quality and idea quantity are largely independent, and that the priming effects of sketch evaluation instructions are small to negligible on idea generation productivity.

Keywords: Design, Sketching, Idea Generation

1. INTRODUCTION

Sketching is an essential skill in engineering conceptual design. Engineers are only taught how to sketch very limitedly, and there are still questions around how much designers' sketching skills influence their design actions. In previous research, it was shown that expert designers can conduct conceptual design without sketching for limited periods of time [1]. However, for longer stretches of designing, sketching offloads working memory freeing the designer to make further decisions [2]. Freeing up working memory is essential during idea generation because working memory resources are a limiting factor of idea generation productivity [3]. The task of sketching also requires cognitive resources, and how much attention is likely influenced by a designers' sketching skill and confidence. Designers who are confident and effective sketchers likely spend less focus on the sketching task freeing up more attention for generating ideas. Further, if designers believe they are in an environment where the quality of their sketches will be evaluated, this could draw more attention to the task of sketching distracting from conceptual design.

The focus of this paper is to explore the priming effects of sketching evaluation language on idea generation productivity and to present preliminary analysis on the relationship between sketching skill and idea generation ability. We compare two groups who received different instructions for an idea generation task. The primed group was instructed that they would be completing tasks of sketching skill and idea generation; the control group was instructed only that they were completing tasks of idea generation. The primed group, therefore, could have implied a sketch quality constraint on their ideation tasks. Both groups generated ideas for the same design prompts then completed a sketching skills task. The two groups are compared to understand the impact of the instructions on idea generation performance. Preliminary analysis of the relationship between sketching skill and idea generation will also be presented. The research is guided by the following research questions.

RQ 1. To what extent does informing designers that their sketching skill will be evaluated influence their idea generation productivity?

RQ 2. To what extent does sketching skill predict idea generation productivity?

2. BACKGROUND

2.1. Sketching in Design

Design research has asserted for some time that engineers need a diverse set of visual representation tools – both formal drafting tools and informal freehand sketching abilities [4]. These freehand sketching skills are of particular interest to the design research community at present because sketching is only minimally taught in most engineering curriculums. An analysis of design notebooks from a capstone design course showed that engineers are not sketching frequently during design unless specifically asked to [5]. This lack of focus and use of freehand sketching is detrimental because more frequent sketching has been shown to correlate with positive design outcomes [6, 7]. Sketching inhibition and behavior can be influenced by sketching lessons and lectures on the importance of sketching [8-10]. Therefore, it is critical to further understand the impacts of sketching skill in design, so that this can inform practicing engineers and educators.

The impact of sketching skill on design activity has only been studied limitedly. During evaluation, the quality of a design sketch influences designers' perceptions of the concept quality and creativity [11, 12]. Conflating these two qualities means that an idea that is subpar could have higher appeal simply due to its visual representation. This could lead to issues with concept selection. During the design process, it has been shown that sketching skill correlates with sketch fluency but not necessarily design outcome [13]. Increasing designers' sketching ability, could improve their use of this visual representation tool in design, which in turn could improve their design outcomes.

Lastly, sketching is crucial in engineering design because it improves engineers' spatial visualization skills [14-16]. Spatial visualization skills are vital for success in many aspects of engineering. The effects of sketching on spatial visualization and academic success are particularly powerful in underrepresented groups [17]. This further emphasizes the benefits of improving sketching skill for engineers.

2.2. Idea Generation

In the original description of brainstorming, Alex Osborn suggested that the goal of brainstorming is generating a large quantity of ideas [18] with the belief that the more ideas generated, the better the odds of finding a good idea. Since then, the productivity of brainstorming has been the focus of much research. Brainstorming groups are hindered by three potential hurdles: production blocking, free riding, and evaluation apprehension [19]. The largest hindrance by far for idea generation productivity for groups is production blocking [20]. However, in this study we are more interested in the effects of evaluation apprehension. We want to know if engineers' idea generation productivity is hindered by apprehension of the evaluation of their sketches.

In idea generation, the focus is not only to find the most ideas, but the most good ideas [21]. Bounded ideation theory states that finding good ideas during idea generation is limited by several factors: understanding, attention resources, goal congruence, stamina, and solution space [3]. Attention resources, in particular, play a key role in the current study. While sketching during idea generation, the task of sketching also requires attention resources. Sketching skill could be a key predictor of how much attention is needed for sketching and how much is free to focus on idea generation productivity. It is important to note though that productivity is not the only important factor in brainstorming. There are actually many tangential benefits for practicing designers of generating ideas in groups [22].

Sketching plays an important role in engineering idea generation. The rapid nature of sketching gives designers an immediate feedback loop in the idea generation process allowing for iterations on design decisions in rapid succession [23]. In this reinterpretation cycle, sketches can stimulate creativity [24]. They also serve to improve access to concepts from the early stages of design [24]. Sketching can also be used to collaborate during idea generation in methods such as c-sketch and 6-3-5 [25].

3. METHODS

The goal of this study is to better understand the relationship between sketching skill and idea generation ability and to understand if sketching evaluation instructions reduce idea generation productivity. These research questions are investigated through independent measures of idea generation ability and sketching skill. Two groups are compared in this study – the difference between the groups being the content of the instructions given to them around sketching skill being measured. This section describes the participants, sampling procedures, measures, research design, and interventions.

3.1. Sampling Procedures

Participants in this study were recruited through an entry-level design and graphics course. The entry-level graphics course is mostly taken by first-year students in engineering. The course teaches students freehand sketching techniques and engineering modeling and drawing using CAD. Data collection was conducted during the lab section of the course at the beginning of the semester. Data collection was conducted after the regular lab activities were over. Participation was completely voluntary, and students were told that they could leave lab early if they did not wish to participate. Students were offered extra credit for participating in the study. Data collection was conducted in 8 sections of the course over 2 semesters: 4 sections in Fall 2021 and 4 sections in Spring 2022. Around 90% of students elected to participate in the study resulting in a full sample size of 356. For this study, we are using a random sample of this larger data set, which represents about 10 percent of the total. The study procedures were approved by the university IRB.

3.2. Participants

The participants for this study are a total of 36 participants. All participants were undergraduate students at a large university in the southeastern United States. Three students did not report demographic data, so the demographic descriptions in this section are partially incomplete. The participants were all engineering majors: 19 mechanical engineering, 12 aerospace engineering, and 2 materials science engineering. Of these students, 7 were first generation college students. The participants were largely underclassmen: 23 were first-year students, 6 were second-year, 2 were third-year, and 2 were fourth-year. The average age of students was 19 with age ranging from 18 to 22. The group contained 25 males, 5 females, and 1 non-binary. Two students elected not to disclose their gender. The race and ethnicities of the participants were distributed as follows: 13 white or Caucasian, 12 Asian, 3 black or African American, 1 Middle Eastern, 3 identified as Hispanic, Latino, or Spanish in origin, and 1 participant was two or more races.

Groups from the Fall 2021 semester and the Spring 2022 were roughly equivalent. The random samples from each semester in this paper had a roughly equivalent distribution of race and ethnicity, a roughly equivalent distribution of ages, a roughly equivalent distribution of academic majors, and a roughly equivalent distribution of first-generation college students. However, the two groups differed somewhat in terms of gender and academic year shown in Tables 1 & 2. In the random sample from Spring of 2022 included no women. In Fall of 2021, there were more second and third year students than there were in Spring of 2022, which was almost entirely first year students.

Gender	FA21	SP22
Female	5	10
Male	14	0
Non-Binary	0	1
Prefer not to disclose	0	2

TABLE 1: DISTRIBUTION OF PARTICIPANT GENDERS BETWEEN SEMESTERS

Academic Year	FA21	SP22
1st Year	11	12
2nd Year	5	0
3rd Year	2	0
4th Year	1	1

TABLE 2: DISTRIBUTION OF PARTICIPANT ACADEMIC YEAR BETWEEN SEMESTERS

3.3. Research Design

The main focus of the research design is obtaining independent measures of designers' idea generation ability, sketching skill, and sketching self-efficacy to better understand the relationship between these constructs. Students were evaluated two times in the entry-level design and graphics course – once in the first lab of the semester and a second time five weeks into the semester after they had received instruction on freehand sketching. This paper only analyzes the first data collection at the beginning of the semester. Students were asked to generate ideas for a design problem, then complete several sketching tasks to evaluate their sketching skill, and finally a brief survey that asked about participants' drawing self-efficacy, demographics, and previous sketching experience. The idea generation task was the only task that was timed. Students were allowed to complete the sketching skills tests and the survey in their own time, and they were dismissed as they finished. Participants generally finished in an hour and a half to two hours with transition time between tasks and instructions.

The instructions given to students prior to the idea generation task varied between the two semesters of data collection to evaluate the potential effects of the priming language. In Fall of 2021, participants were informed before the idea generation task that they would be evaluated on sketching skill. In Spring of 2022, participants were not informed that their sketching skills would be evaluated until after the idea generation task was complete. The group that was informed that sketching skills would be evaluated is considered the primed group. The knowledge that their sketching skills were under consideration could have impacted the way they carried out the sketching tasks. The specific priming language used in the prompts is detailed below.

The group that received the instructions priming them for their sketching ability to be evaluated received the following instructions:

> *In this research study this semester, we are investigating relationships between sketching ability and idea generation ability. During this time, we are going to ask you to complete three tasks: (1) an idea generation task (this will take about 45 minutes), (2) a sketching skills task (this will take about 10 minutes), and (3) a brief survey (this will take about 5 minute).*

The above instructions emphasize the relationship between idea generation and sketching ability. Even though explicit tasks were called out to evaluate each skill, participants' sketching behavior may have been influenced by the language.

In the Spring 2022 semester, the language of the script was revised to keep participants blind to the assessment of sketching and the investigation of the relationship between sketching skill and idea generation. The script also emphasized that the data collection was independent of the entry-level course that the students were in, so that they would not infer any sketching constraints from the course content. Spring 2022 script excerpt:

> *In this research study this semester, we are investigating idea generation ability in connection with engineering design. You will be asked to complete several tasks today… This research this semester is independent of the [entry-level design & graphics] course. …The first task today is an idea generation problem in which you will be given 45 minutes to generate as many ideas as you can to a given design prompt.*

In this study, we will compare the performance of these two groups on the idea generation and sketching tasks to understand to what extent this language impacted their performance. The following sections detail the specifics of how idea generation, sketching ability, and drawing self-efficacy were evaluated.

3.4. Idea Generation

Idea generation abilities were measured through two mechanical design problems: the peanut sheller problem and the corn shucker problem. The peanut sheller problem asked students to design a device to shell a large number of peanuts quickly without access to electrical outlets. The corn shucker problem asked students to remove the husk and silk from a large amount of corn quickly with minimal damage to the kernels. Both problems are shown in full in Appendix A. These two problems were selected because they have shown to be equivalent in terms of average quantity of ideas and this study required two different design problems. All students saw each design problem only once, generating ideas for one prompt at the beginning of the semester and for the other prompt after sketching instruction. The problems were assigned at random to each section of the course balancing the sections so that approximately half of the students were assigned to each problem before and after sketching instruction. The random distribution was applied to an entire course section instead of individual students in an attempt to reduce participants' exposure to the other design problem.

Students were given 2 minutes to review the design problem and 45 minutes to generate solutions to the problem. A time limit of 45 minutes for idea generation was selected because it was long enough to give ample time for sketched solutions and short enough to be completed in the class time allotted. Previous research has shown students will generate more ideas if given more time up to 2 hours, so 45 minutes was thought to be ample time without inciting fatigue [27]. In addition, around 45 minutes has been used in past studies with this particular design problem. Some students stopped generating ideas before the allotted time, but generally towards the end of the session. Students were not allowed to work on anything else or do any other activities during the allotted idea generation time. Participants were asked to sketch one solution per sheet and annotate their ideas to make them clear. If students ran out of pages in their packet, they could raise their hand to ask for more sheets.

Idea generation ability was evaluated using the quantity measure for ideation effectiveness [28]. This measure has been adapted by Linsey et al. to increase the reliability of quantity measure [29]. Quantity is assessed as a count of all non-redundant ideas in an idea set. Linsey et al. introduced assessing this quantity using the functional basis as a guide [30, 31]. Each solution generated for the design problem can contain several ideas. An idea is a specified form in the solution that fulfills a function of the solution as defined by the functional basis. If the same form fulfills multiple functions, then that form is counted as multiple ideas. Ideas must be shown to be counted, either as sketches or words, not just implied. If the same form is repeated in multiple of a participant's solutions to accomplish the same function, this is considered a redundant idea and does not contribute to the count past the first occurrence.

Two raters evaluated a portion of the idea generation data to check for inter-rater reliability. One rater was a graduate student in mechanical engineering with several years of experience in design research. The second rater was a senior undergraduate student in mechanical engineering with a concentration in design. The two raters iterated several times discussing what justified an idea by the functional basis and to what degree ideas must differ to be counted as non-redundant. The two raters then evaluated 10 participants' data for both the peanut sheller problem and the corn shucker problem. The Pearson correlation between the final quantity counts from the two raters were $r(8) = 0.871$, and $r(8) = 0.990$ for the two problems respectively.

3.5. Sketching Skills

Sketching skills were evaluated using the Sketching Foundations Test [32, 33]. Students were asked to draw a cube, a cylinder, and a camera in two-point perspective. For the cube, sketchers were given the front edge and starting lines in perspective to guide their sketch. For the cylinder, sketchers were provided full construction lines for the cylinder and simply asked to sketch the cylinder within the rectangular prism. For the camera task, sketchers were shown the simple camera constructed of a combination of primitives in three orthographic views shown in Figure 1. Examples of these tasks are shown in Figure 2.

The task was completed on paper. Students could complete the task using pen or pencil. However, they were not allowed to use any straight edges for their construction lines or final lines. All sketching had to be completed freehand. There was no time limit for this task.

The sketching foundations test was evaluated by independent ratings of overall sketch quality. Each sheet of the test was evaluated on a scale of 1 to 5. Two independent raters evaluated each of the sketches, and their ratings were averaged for the score for that sheet. The scores for the three sheets – cube, cylinder, and camera – were then summed for a final sketching skill score. The theoretical range of scores was from 3 to 15. Three raters each rated a portion of the data for this study: a mechanical engineering graduate student who had been trained in two-point perspective sketching techniques, an industrial design graduate student with experience evaluating sketching, and an undergraduate industrial design student with expertise in perspective sketching. Raters were told to evaluate each sketch based on overall quality. They were also told to use the whole scale while rating, meaning that sketches are evaluated on a relative scale based on the sample, not a theoretical scale. The sketches were displayed in a random order, and raters were kept blind to the condition of the participants. The inter-rater reliabilities of the ratings were evaluated using the two-way mixed intraclass correlation coefficient for absolute agreement and average measure. The inter-rater reliability found for this study for the cube sketches was ICC = 0.873, for the cylinder sketches ICC = 0.843, and for the camera sketches ICC = 0.749.

3.6. Drawing Self-Efficacy

Sketching self-efficacy was evaluated using the Drawing Self-Efficacy Instrument (DSEI) [34]. The DSEI is a validated survey instrument designed to evaluated confidence in drawing abilities. The DSEI consists of 13 items asking about confidence on a scale of 0 to 10 in different drawing circumstances. A subset of items from the DSEI are shown below for reference:

- Drawing to communicate with others
- Drawing to explain or teach a concept to others
- Drawing a 2D object
- Drawing a 3D object
- Drawing a portrait
- Drawing a vehicle
- Drawing to think through a problem

Responses to the items were averaged for a final DSEI score for each participant.

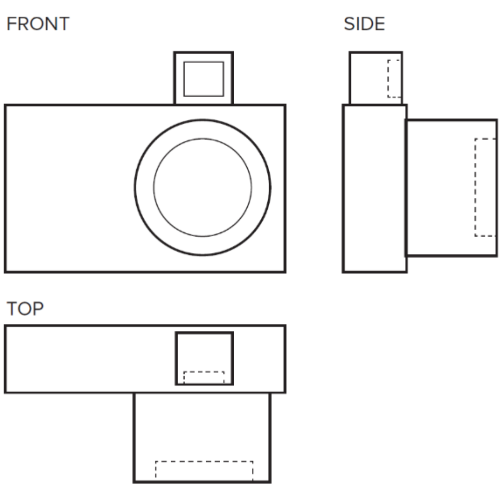

FIGURE 1: SKETCHING FOUNDATIONS TEST CAMERA SKETCH PROMPT

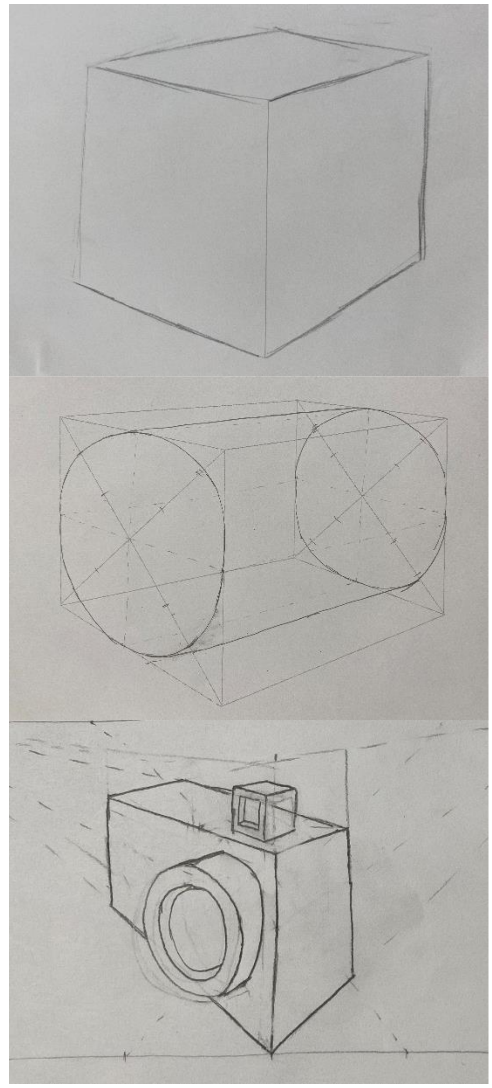

FIGURE 2: EXAMPLES OF SKETCHING FOUNDATIONS TEST SKETCHES

4. RESULTS AND DISCUSSION

For the idea generation activity, the average number of ideas generated was $\bar{X} = 13.5, SD = 5.2$. The average number of ideas generated for the peanut sheller problem was $\bar{X} = 13.4, SD = 4.7$, and the average number of ideas generated for the corn shucker problem was $\bar{X} = 13.5, SD = 5.9$. Idea generation quantity was not normally distributed by the Shapiro Wilk test (W = 0.917, p = 0.012). A Mann Whitney U-test for independent samples showed there was no significant difference in quantity of ideas generated between the peanut and corn problems ($U\ (34) = 120, p = 0.301$).

Each of the three pages of the Sketching Foundations Test was rated for overall quality on a scale of 1 to 5. The average quality for the Cube, Cylinder, and Camera items are shown in Table 3. The total score on the Sketching Foundations Test ranged from 3 to 12. The average total sketch quality score for participants was $\bar{X} = 7.73, SD = 2.43$. The sketching skill scores were normally distributed using a Shapiro Wilk test (W = 0.971, p = 0.471).

	$\bar{X}$	SD
Cube	2.85	0.96
Cylinder	2.39	0.90
Camera	2.50	0.94
Total	7.73	2.43

TABLE 3: AVERAGE SKETCH QUALITY BY TEST ITEM

The average score on the Drawing Self-Efficacy Instrument (DSEI) was $\bar{X} = 5.69, SD = 2.19$. The DSEI scores were normally distributed by a Shapiro Wilk test (W = 0.947, p = 0.092). The two items that scored highest among participants were "*Drawing a 2D object*" ($\bar{X} = 7.2$) and "*Drawing to think through a problem*" ($\bar{X} = 7.1$). The two items that scored the lowest among participants were "*Drawing a portrait*" ($\bar{X} = 3.6$) and "*Drawing a vehicle*" ($\bar{X} = 4.7$).

4.1. Priming Effects

RQ 1. To what extent does informing designers that their sketching skill will be evaluated influence their idea generation productivity? To understand the potential of priming effects that the sketching evaluation instructions had on individuals, sketch quality and drawing self-efficacy were compared between the two groups. An independent samples t-test showed there was no significant difference in sketch quality between the two groups ($t(33) = 1.072, p = 0.29$). Students who received the priming instructions scored on average $\bar{X} = 8.13, SD = 2.81$, and students who did not receive the priming instructions scored on average $\bar{X} = 7.25, SD = 1.86$. An independent samples t-test showed no significant difference in scores on the drawing self-efficacy instrument either ($t(34) = 0.927, p = 0.36$). Students with priming self-reported an average of $\bar{X} = 6.00, SD = 2.04$, and students without priming reported an average of $\bar{X} = 5.31, SD = 2.39$. This speaks further to the similarity of the groups being compared. Though the primed group and the control group were from different semesters, they did not differ significantly in sketching skill or drawing self-efficacy.

We then analyzed the differences in idea generation between the two groups to examine the priming effects of the sketch evaluation language on idea generation abilities. An independent samples t-test revealed no significant difference in the quantity of ideas generated by the two groups ($t(34) = -0.528, p = 0.594$). The group that received priming generated on average $\bar{X} = 13.05, SD = 5.54$, and the group that did not receive priming generated on average $\bar{X} = 14.00, SD = 4.90$.

To further examine the impacts of the priming language, we looked at idea generation quantity in the context of individuals' sketching skill. Multiple linear regression was used to determine if the interaction of the priming condition had a significant effect on the sketching skill predicting idea generation productivity. All assumptions were met for linear regression: residuals were normally distributed on a normal probability plot and there was no relationship between residuals and the fitted values. The overall regression was not statistically significant $F(3, 31) = 0.597, p = 0.622$. The interaction between priming condition and sketching skill was not a significant predictor of idea generation quantity ($\beta = -0.211, p = 0.809$). The scatterplots of quantity and sketch quality are shown for the priming and no priming condition in Figure 3 and Figure 4.

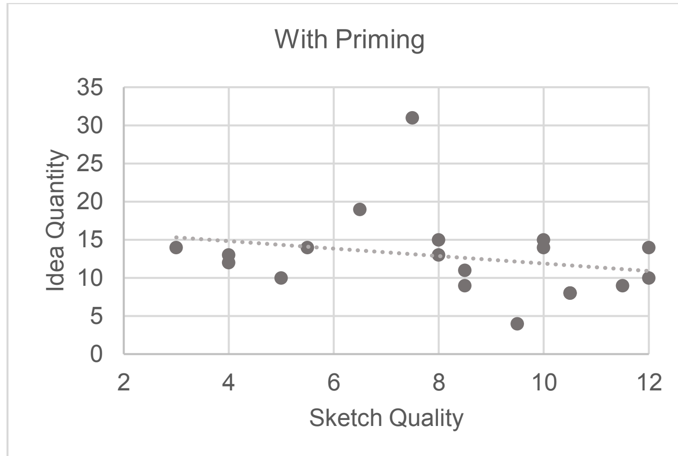

FIGURE 3: SCATTERPLOT OF SKETCH QUALITY AND IDEA QUANTITY WITH PRIMING

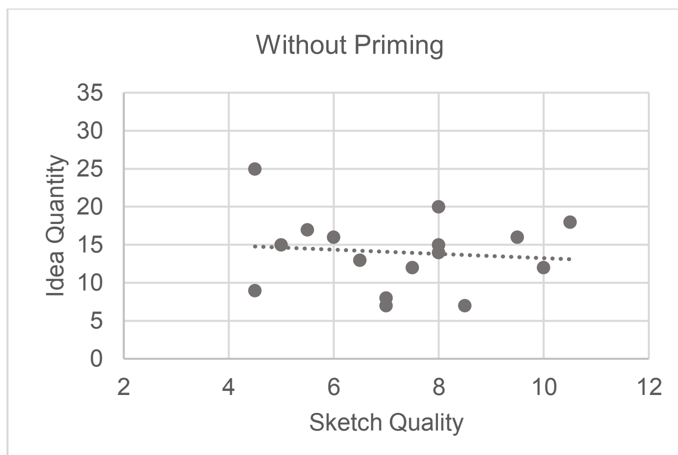

FIGURE 4: SCATTERPLOT OF SKETCH QUALITY AND IDEA QUANTITY WITHOUT PRIMING

The priming effects of sketch evaluation language appears to have negligible effects on the productivity of sketch-based idea generation. Students who were informed of the goal of the research study and informed that their sketching skills would be evaluated did not perform measurably different than students not informed of sketch evaluation in terms of quantity of ideas generated. There was no difference in the average number of ideas generated by the two groups. If there had been significant effects from the differing instructions, the group informed of sketching evaluation would likely have generated fewer ideas due to more attention resources being put towards sketching.

Further, the relationship between sketching skill and idea quantity did not significantly differ between the two groups. The linear regression for both the group with priming and the group without priming was trending towards a negative relationship. At this point there is no evidence to support that the differing instructions had any impact on student behavior.

4.2. Sketching Skill & Idea Generation Ability

RQ 2. To what extent does sketching skill predict idea generation ability? Because the differences in performance between the two groups was negligible, the data can be combined to conduct a stronger analysis of the relationship between sketching skill and idea generation. Simple linear regression was used to test if sketching quality significantly predicted quantity of idea generated. The data met all the assumptions for linear regression: the residuals were roughly normally distributed by inspection of a normal probability plot of the residuals and there was no observable relationship between the residuals and the predicted values. The fitted regression model was $idea\ quantity = -0.465 * sketch\ quality + 13.34$. The overall regression was not statistically significant, $\mathrm{F}\,(1, 33) = 1.613, \mathrm{p} = 0.213$. Sketch quality did not significantly predict idea quantity ($\beta = -0.465, p = 0.213$). The scatter plot for the relationship is shown in Figure 5.

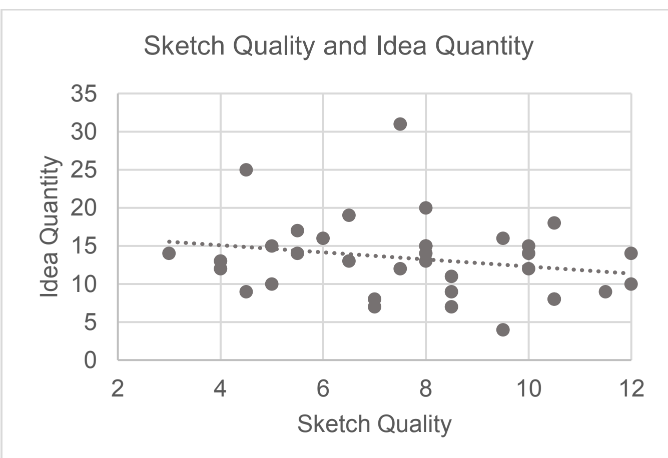

FIGURE 5: SCATTERPLOT OF SKETCH QUALITY AND IDEA QUANTITY

In addition to examining sketching skill, the relationship between drawing self-efficacy and idea quantity was examined. Confidence in sketching skill could just as likely predict sketching behavior during idea generation. Simple linear regression was used to test if DSEI significantly predicted idea quantity. All assumptions for linear regression were met: the residuals were normally distributed and there was no observable relationship between the residuals and predicted values. The fitted regression model was $idea\ quantity = -0.062 * DSEI + 13.34$. The overall regression was not statistically significant, $F(1,33) = 0.023, p = 0.881$. DSEI did not significantly predict idea quantity ($\beta = -0.062, p = 0.881$). The scatterplot for the relationship between DSEI and idea quantity is shown in Figure 6.

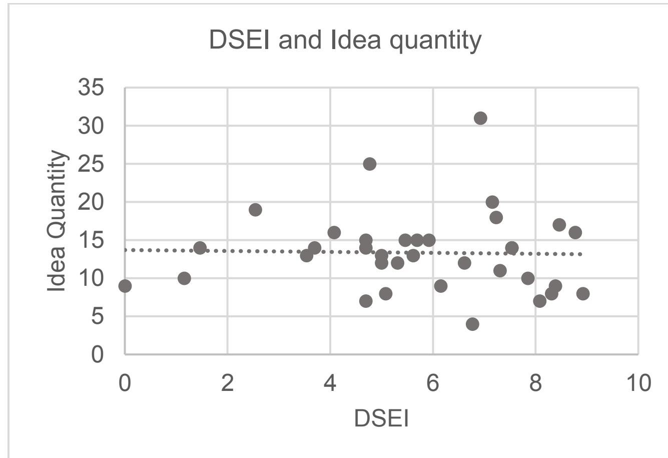

FIGURE 6: SCATTERPLOT OF DSEI AND IDEA QUANTITY

These data shed interesting light on the relationship between sketching and idea generation. Largely, the relationship between sketching skill and idea generation appears to be independent or at the very least not very strong. This suggests that other factors are much more prominent for driving idea generation productivity. This is surprising as it suggests that the effectiveness and confidence with which we visually represent our ideas does not significantly affect our generation of new ideas. This suggests that designers are finding ways to represent concepts even when they are not confident or skilled at sketching them. At least in terms of productivity, high quality sketching skill may not be that impactful.

However, this raises questions about how sketching skill impacts the other aspects of ideation effectiveness such as novelty and variety. If sketching skills do not enable productivity, do they enable more unique or a wider variety of ideas? If a designer is limited in their sketching skill or confidence, can they represent more unique or diverse ideas?

Lastly, even though the results regression analysis were insignificant, the relationship between sketching skill and idea generation ability was trending negative. This suggests that designers with higher sketching quality may be less productive in idea generation. It could be that they are dedicating more time and effort to express ideas more clearly because they have the capability to do so, and this in turn is slowing down their idea generation productivity. However, further data and analysis is needed to make any decisive conclusions. In this study, only first year students were evaluated. It would be interesting to compare individuals with much greater sketch abilities.

The data presented in the paper represent preliminary findings from a random subset of a much larger data set. Future work will investigate these relationships with much higher power to make more meaningful conclusions on the relationships in question here. Future work will also expand the evaluation of idea generation to include measures of novelty, variety, and quality. Sketching skill may have more significantly predict other aspects of idea generation effectiveness.

4.3. Limitations

The results presented in this paper are preliminary findings from a larger data set. The smaller sample size will be expanded upon in future work, but it is a major limitation to the scope of conclusions that can be drawn in this paper. The first question asked in this paper regards the comparison of two quasi-experimental groups. Having the two priming conditions in different semesters is a major limitation. There are many factors that change from semester to semester especially when examining students enrolled in the same course across fall and spring semesters. Ideally, the different instructions would have been given to different sections of the course in the same semester. However, because there was not a significant difference between the two groups, this limitation is less problematic. It is also a limitation that some students stopped generating ideas before the allotted time had run out. This could present a confounding factor between sketching skill and idea generation ability.

5. CONCLUSION

In the context given in this experiment, informing students of sketch evaluation has negligible impact on idea generation productivity of engineering designers. Questions still remain about the nature of the relationship between sketching skill and idea generation ability.

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APPENDIX A – IDEA GENERATION DESIGN PROMPTS

Peanut Sheller Problem

In places like Haiti and certain West African countries, peanuts are a significant crop. Most peanut farmers shell their peanuts by hand, an inefficient and labor-intensive process. The goal of this project is to design and build a low-cost, easy to manufacture peanut shelling machine that will increase the productivity of the African peanut farmers. The target throughput is approximately 50 kg (110 lbs.) per hour.

Customer Needs:

- Must remove the shell with minimal damage to the peanuts.

- Electrical outlets are not available as a power source.
- A large quantity of peanuts must be quickly shelled.
- Low cost.
- Easy to manufacture.

Please sketch and note (with words) one design solution per page starting on the next page.

Corn Shucker Problem

Corn is currently the most widely grown crop in the Americas with the United States producing 40% of the world's harvest. An ear of corn has a protective outer covering of leaves, known as the husk, and strands of corn silk threads run between the husk and the kernels. The removal of husk and silk to clean the corn is known as shucking corn. Design a device that quickly and cheaply shucks corn for mass production.

Customer Needs:

- Must remove husk and silk from corn cob with minimal damage to kernels.
- A large quantity of corn must be shucked quickly.
- Must be safe for user
- Low cost.
- Easy to manufacture

Please sketch and note (with words) one design solution per page starting on the next page.