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EDGD Calendar of Events

Future ASEE Engineering Design Graphics Division Midyear Conferences

EDGD Midyear Conference – future dates are pending

Future ASEE Annual Conferences

Year	Dates	Location	Program Chair
2027	June 20 - 23	Toronto, Ontario, Canada	
2028	June 11 - 14	Pittsburgh, Pennsylvania	
2029	June 17 - 20	San Francisco, California	

If you're interested in serving as the Division's program chair for any of the future ASEE annual conferences, please contact the Director of Programs, Erik Schettig

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Message from the Editor

Nancy E. Study, *EDGJ* Editor
Penn State Behrend

To follow up from my last letter, I am pleased to report that our submissions continue to increase as we are making small steps forward to keep the Journal viable to instructors and researchers in engineering graphics. We still need your help in encouraging your colleagues and graduate students to submit articles that meet the Journal's scope. Please refer to the information on our website and look for our calls for manuscripts on the EDGD listserv and other related listservs.

At the Annual Conference in Charlotte, we had a very productive Division business meeting and brought new people on board to help with the Journal's production and reviews. If you are interested in serving the Journal as a reviewer or as a member of the Advisory Board, please contact me.

The Journal staff welcome your feedback as we continue to move forward in the changing environment of academia and publishing, especially with the advent of AI that some authors are using in their writing, and a few journals are using in their review process. We remain committed to not using AI in our review process and are working on a formal policy for its use in authoring submissions.

As always, I thank Judy Birchman for her able assistance in doing the copyediting, the staff at East Carolina University, and all the Journal's reviewers for their timely feedback. Hope to see you all in Toronto.

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The Relationship Between Spatial Visualization Skills and Sketching

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Abstract

Academia trains engineering students to have strong technical content knowledge through various courses, work experiences, or capstone projects. Two skill sets engineering students are likely to have utilized throughout these experiences are spatial visualization skills and sketching skills. Spatial skills are a key indicator of interest, decision to major, and later success in various fields of engineering. Sketching can aid in project design ideation, improve design conceptions over iterations, and can be an effective way to communicate complex information to different audiences. Spatial skills can be trained through explicit courses, interventions, and typically the natural progression through an engineering major. Likewise, sketching skills can be trained through courses and interventions; however, with the advent of more technological drawing tools such as CAD, these skills may not be adequately trained. This research examines relationships between spatial skills and sketching skills for first-year engineering students enrolled in a two-semester introductory engineering course at a large Midwestern R1 institution. A total of 35 participants completed all spatial instruments and opted to generate a sketch. A principal component analysis was applied to categorize participants into low, medium, or high visualizers. The types of sketches the participants generated included orthographic, pictorial, and schematic sketches. Analysis of the low and high spatial visualizer sketches revealed that low spatial visualizers generated sketches with more details, annotations, and information regarding their project demonstration or their robot; conversely, high spatial visualizers provided sparser sketches of smaller, specific components of their robot, or opted to provide a simple overall view without as much detail. These results are then connected to prior literature that has explored sketching and spatial skills and implications are discussed.

Introduction

Spatial Skills in Engineering

Spatial skills are a strong indicator of an individual's decision to major in engineering and be successful in the discipline (Lane & Sorby, 2022; Loney et al., 2019; Ramey & Uttal, 2017; Shea et al., 2001; Uttal & Cohen, 2012; Yoon & Mann, 2017). Spatial skills are often defined as one's ability to "visualize objects and situations in one's mind, and to manipulate those images" (Sorby, 2007, p. 1). Spatial skills are important cognitive skills in general but are particularly important in engineering majors, which often rely on more mental imagery or the ability to generate and navigate multiple viewpoints compared to other fields. Spatial skills are not static, as multiple studies have shown that these skills are malleable and trainable through interventions (Ramey & Uttal, 2017; Sorby, 2007; Sorby, 2009; Uttal et al., 2013). Research has shown differences in spatial skills based on gender and socioeconomic status (Casey et al., 2011; Newcombe & Shipley, 2015; Wai et al., 2009); the training of these skills could lead to improved representation and success in engineering.

Sketching in Engineering

Another skill that research has demonstrated as important for success in engineering is the ability to sketch effectively. Sketching has been shown to be important to the engineering design process and as a way to physically represent complex aspects of engineering projects (Ishak et al., 2015; McGown et al., 1998; Schutze et. al., 2003; Song & Agogino, 2005). Sketching plays an important role in the early stages of project development and can be a useful tool for students who may have trouble fully conceptualizing project designs mentally (Yang & Cham, 2007). Sketching is

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just as powerful as written and oral communication (Rose, 2005; Westmoreland et al., 2011) and can aid in an engineering design team's productivity, their shared visual representations of projects (Booth et al., 2015; Goldschmidt, 2007) and provide a means to communicate information to other experts (Jeong, 2019). Other researchers have stated that sketching is the most "traditional and quickest way to communicate technical information…[and] creating and using drawings and sketches is the engineer's way to work" (Schmidt et al., 2012, p. 304). Despite the empirically validated importance of sketching skills and interventions that can improve them (Booth et al., 2016; Jeong, 2019; Weaver et al., 2022), there appear to be multiple factors that contribute to why sketching may not be used as much by engineering students. Some factors are access to computer-aided drawing software and a lack of comprehension of the role of sketching in design (Schmidt et al., 2012). Prompts are also a critical indicator of a student's decision to sketch, with specific guidelines and instructions impacting sketch generation and quality (Rose, 2005; Weaver et al., 2024). The decision to sketch is multifaceted and complex. Regardless, efforts have been made to return to pure free-hand sketching based courses through interventions and modifications, a particular one being the improvement of spatial skills.

Intersections between Spatial Skills and Sketching Skills in Engineering

Training spatial skills often includes a mixture of freehand sketching instruction, the introduction of 2D and 3D modeling, orthographic projection, perspective sketching, and isometric sketching either through workshops, lectures, or additional content provided to the students (Raju & Sorby, 2024; Sorby, 2022; Youssef & Berry, 2012; Weaver et al., 2022). It is important that this training provides multiple opportunities to sketch in various forms for students, as other research has found that "most of the improvements in spatial visualization occurs during the sketching instruction portion of the class, not the CAD portion" (Weaver et al., 2022, p. 1846). However, it has been hypothesized that well-developed spatial visualization skills may result in a student not sketching. Authors have stated that "today's students do not sketch as much as engineers of earlier generations…[instead] students prefer to visualize (and solve) design problems in their heads instead of on paper" (Westmoreland et al., 2011, p. 1). Yang & Cham explored sketching skill in the design process and found "a common complaint among some students is that they do not want to keep [sketch] logbooks because their work is already all in their head" (2007, p. 479-481). Overall, there are various ways to instruct and improve spatial and sketching skills, and often both skills are targeted simultaneously, potentially providing engineering students with an improvement to two proficiencies that will have broader impacts on their future engineering design processes and success in their engineering studies.

Methodology

Data was collected from first-year engineering students at a large Midwestern US R1 institution. The participants were enrolled in the second course of a two-course sequence taken by all engineering majors at the university. Students complete a team-based project where they build an autonomous robot based on real world examples of disaster relief. The students' robot must not use wheels, must navigate uneven terrain, be able to pick up waste objects in bins, determine what waste it is via weight, and have the robot drop off the waste at the proper location. Teams are made up of three to four students, with each student typically adopting a specific role of coder, project manager, builder, or documenter. Participants explicitly practiced spatial thinking skills and sketching in the first-semester course through two weeks of in-class activities and graded assessments. The data used in this research was collected across two phases; the first phase involved a monitored online video call where students

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completed a battery of spatial tasks, and the second phase involved an approximately hour-long one-on-one interview with a member of the research team that involved technical communication tasks and discussions of their robotic project from the previous semester.

Phase One Instruments

Spatial Skill Measurements

The spatial skills of the participants were measured with the Mental Rotation Test (MRT) (Vandenburg & Kuse, 1978) and the Mental Cutting Test (MCT) (CEEB, 1939). In the MRT, participants are given a criterion figure on the left and must select two of the four images on the right that represent the criterion figure in a rotated position; both selections must be correct in order to earn a point for the question. An example of an MRT question is provided in Figure 1.

In the MCT, participants are shown a criterion figure with an imaginary cutting plane through it and are asked to determine the correct resulting cross-section from the five choices given. Participants are given a total of 20 minutes to complete 25 questions with 1 point per each correct cross-section selected. An example of an MCT question is shown in Figure 2.

Demographic Measurements

Two final instruments in phase 1 included a self-reported confidence questionnaire and self-reported demographic information (e.g. gender, parent's education, GPA).

Phase Two Instruments

Participants who successfully completed all Phase One instruments were invited to complete another set of instruments in a face-to-face video recorded interview session with a member of the research team. The sketching data was collected as part of a larger written communication task. Participants were tasked with generating a written document that described their robotic design project based on these questions:

- What problem were you trying to solve?
- What task was it supposed to do?
- What did it look like?
- How did it operate?
- What features of your robot solved the problem?
- How did your robot perform in the demo?
- If you need to include a figure in your document, please use the blank sheets

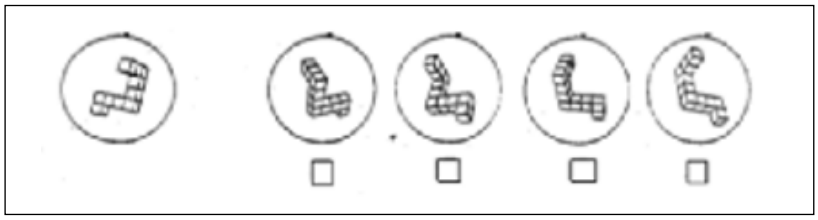


Figure 1. *Example MRT problem (correct answer = 1, 3).*

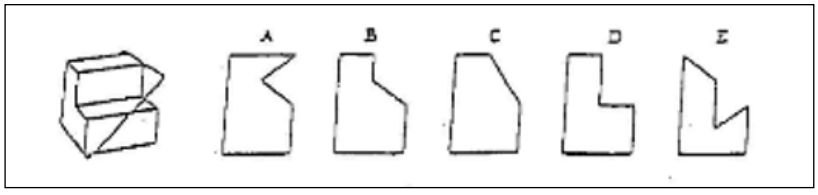


Figure 2. *Example MCT problem (correct answer = D).*

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of paper provided and hand-sketch the figure. Do not spend a great deal of time trying to make a computer-generated sketch either in Word or elsewhere. Your document should be 2 pages maximum.

Sketches that were generated by participants were gathered and categorized as described in the following.

Results and Analysis

All data analysis was conducted in RStudio 2026.01.1 Build 403 where appropriate. A principal component analysis was applied to participants MRT and MCT scores to generate a single spatial visualization score; this score was used to categorize participants into the spatial ranks of low (n = 12), medium (n = 60), and high (n = 14) spatial visualizers. After rank categorization, all participants that generated a sketch (n=35) were analyzed. A system of rubric grading and rank categorization based on holistic quality was applied. All generated sketches were grouped into three categories: orthographic, schematic, and pictorial. Sketches that had an at least one orthographic view or a 2D sketch of a specific part of the robot (i.e. a detail view) were placed into the orthographic category (n=22); sketches that displayed the pathways the robot had to take or how the project demonstration occurred were placed into the schematic category (n=7); sketches that displayed only a pictorial view of their robot were placed into the pictorial category (n=6). A rubric was developed and applied to the orthographic sketches (see Appendix A). The rubric contained five Likert scale questions (1: Not Applicable, 2: Marginal, 3: Adequate, 4: Above Average, 5: Strong). Cohen's squared kappa resulted in a kappa of 0.85 (z=8.96, p=0); the individual question kappa was 0.64, 0.95, 0.85, 0.81, 0.72 for questions 1-5 respectively. A two-way mixed-effects model for intraclass correlation resulted in an ICC(A,1) = 0.85, and ICC(C,2) = 0.92. Raters had moderate/substantial agreement on each question and very strong agreement on the final score of each orthographic sketch; non-orthographic sketches were ranked by both raters simultaneously.

Descriptive Statistics for all Participants

A total of 86 participants completed all phases, and 35 generated a sketch, of which a smaller portion were low and high visualizers. Gender was not considered as its variance was approximately equal between high and low visualizers that generated sketches; medium spatial visualizers were not examined to focus on how both ends of the spectrum of spatial visualization skill interact with sketching. Specifically, these two populations were examined to find trends on how individuals that may struggle with engineering (low visualizers) and those that may be more proficient in engineering (high visualizers) generate sketches for design problems. Other factors such as written report responses, prior reading/writing training, and comprehension of provided tasks were not examined as this research specifically focused on spatial skills and sketching. While these aspects likely impact motivations behind creation of a sketch or information deemed necessary to be included in sketches, those examinations are outside the scope of this work's research question; these will be considered when larger populations are examined.

High spatial visualizers had larger variations in spatial scores as some individuals scored near perfect, while others bordered above medium spatial skill (Table 1). All low spatial visualizers

Table 1

Means (SD) of sketch participants spatial scores.

Variable	Low Visualizers (n=5)	High Visualizers (n=6)
Spatial Score (out of 100)	6.26 (5.41)	86.21 (12.47)

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had similar scores. Overall, the power of this sample size was too small to generate meaningful quantitative results. The following discusses the set of sketches and provides the spatial score of the participant that generated their sketch and the sketch's rank or rubric score.

Schematic Sketches

These types of sketches focused on specific tasks for the robot, often the movements the robot had to complete during the demonstration. These sketches were labeled as schematic since they focused on the physical layout of the demonstration or task, with the robot either missing or simplistic. The following two schematic sketches were completed by low visualizers.

For Figures 3 and 4 the text and arrows are nec-

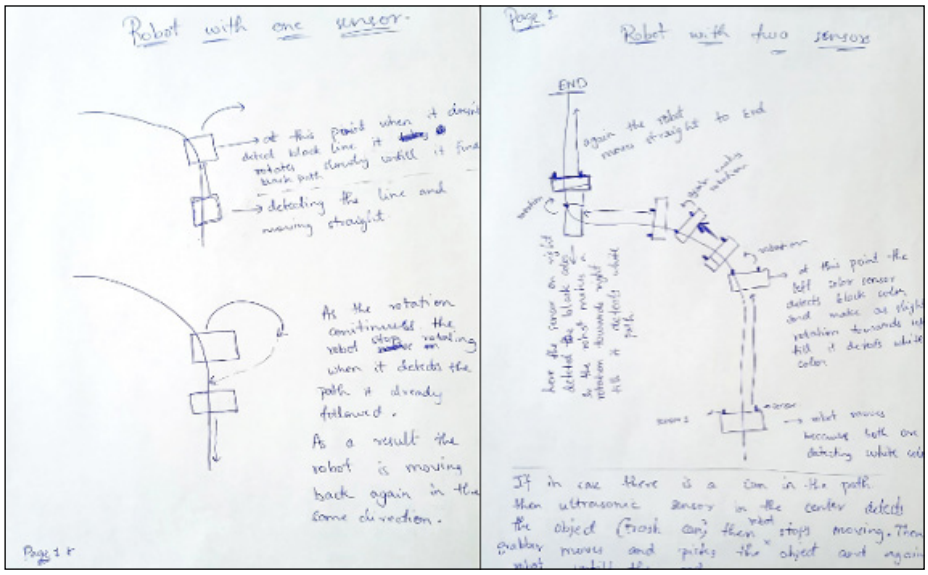


Figure 3. *Low visualizer schematic sketch #1 (Sketch rank: 1 out of 7, Spatial score: 4%).*

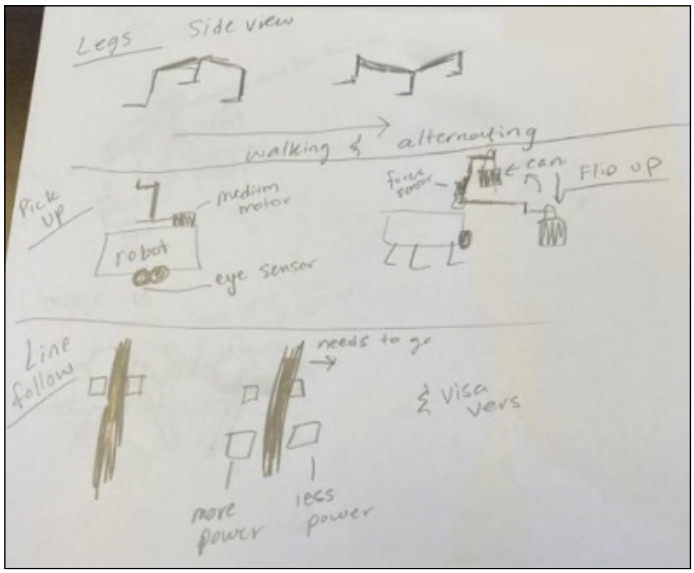


Figure 4. *Low visualizer schematic sketch #2 (Sketch rank: 3 out of 7, Spatial score: 0%).*

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essary for these schematic sketches to be comprehensible. Furthermore, the annotations and labels go beyond pointing out key components of the robot and provide deeper insights for how operations of the robot were supposed to occur. Schematic sketches appear to represent one or more tasks to be performed by the robot, whether it be movement of legs, rotation, and operation of sensors, or grabbing operations.

Pictorial Sketches

Two high spatial visualizers opted to generate pictorial sketches during the communication task as shown in Figures 5 and 6 below. All participants had practiced isometric sketching in the previous semester and all pictorial sketches that were generated contained a single view of the robot.

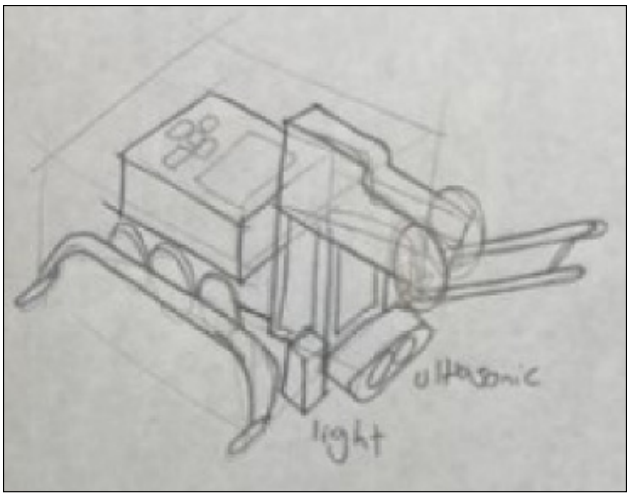


Figure 5. *High visualizer pictorial sketch #1 (Sketch rank: 2 out of 6, Spatial score: 100%).*

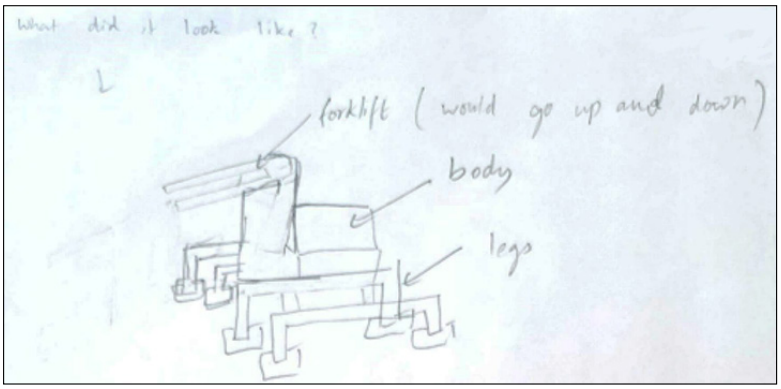


Figure 6. *High visualizer pictorial sketch #2 (Sketch Rank: 5 out of 6, Spatial Score: 76%).*

Both sketches (Figures 5 and 6) have noticeably less text than the schematic sketches but illustrate an overall view of the robot the participants designed. The labels on both sketches point out the forklift and parts of the body; pictorial sketch 1 (Figure 5) shows the specific sensors used, ultrasonic and light, and while it does not point out the lifting mechanism, it can be understood easily from the image. While these two sketches have slightly neater lines and focus on the robot itself over the tasks the robot was meant to perform, it is harder to discern the precise leg movements of these robots from the sketches. Overall, the high visualizers' pictorial sketches do an effective job at giving a visual at-a-glance view of the entire robot and some aspects of the tasks, such as lifting an object; however, it is more difficult to visualize the movement of the legs without the inclusion of more arrows, labels, or further perspectives of these sketches.

Orthographic Sketches

Due to the larger sample size in this sketch category, a validated rubric was applied. The following figures and descriptions detail the low and high visualizer orthographic sketches with scores from the sketching rubric (max score of 25 points). These sketches are ordered based on the total spatial visualization score for the participant acquired in phase 1 (out of 100%), from lowest to highest.

Low Visualizer Orthographic Sketches

All low visualizer orthographic sketches did not include a detail view or a specific zoom in on elements of the robot to provide further information. Figures 7 and 8 are all a single orthographic side

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view with all having a large number of labels. The annotation details in Figure 7 describe the specific tasks the robot was to perform and Figure 8 includes annotations to specify locations of sensors and has utilized arrows to signify motion of the claw. Figure 9 includes two orthographic projections, a front and side, but only labels these views and provides no further detail; this figure is the weakest out of this group of sketches.

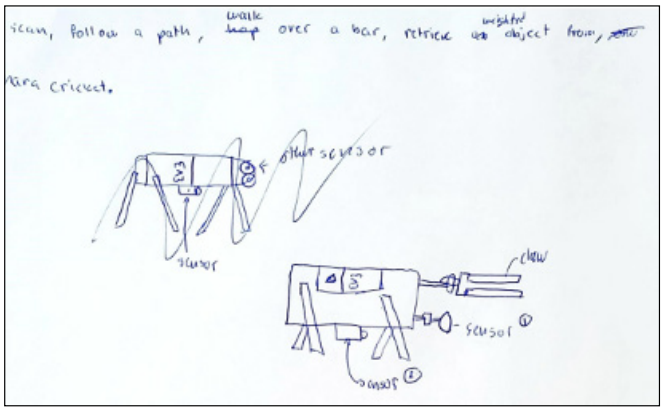


Figure 7. *Low visualizer orthographic sketch #1 (Sketch score: 12.5 points, Spatial score: 4%).*

High Visualizer Orthographic Sketches

All four high visualizer orthographic sketches contained detail views, with Figures 10 and 12 consisting of only a single detail view. Figures 10 and 12 both used annotations to focus on the legs of the robot; while this does provide information on the movement operations of the robot the overall robotic object is not discernable.

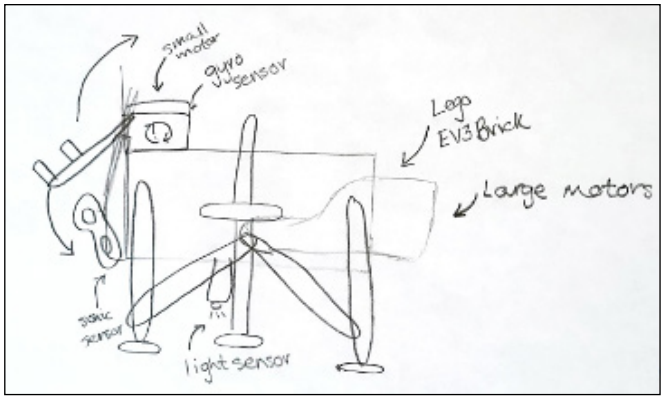


Figure 8. *Low visualizer orthographic sketch #2 (Sketch score: 13.5 points, Spatial score: 9%).*

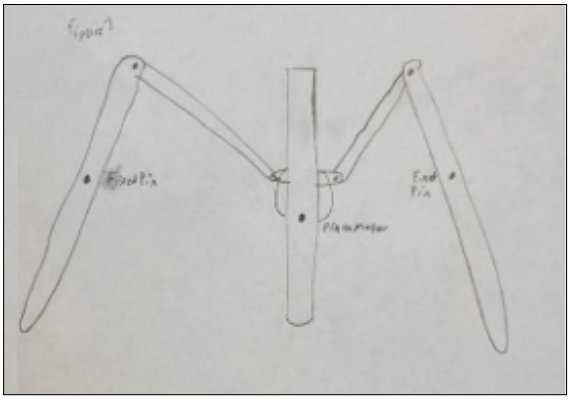


Figure 10. *High visualizer orthographic sketch #1 (Sketch score: 9.5 points, Spatial score: 74%).*

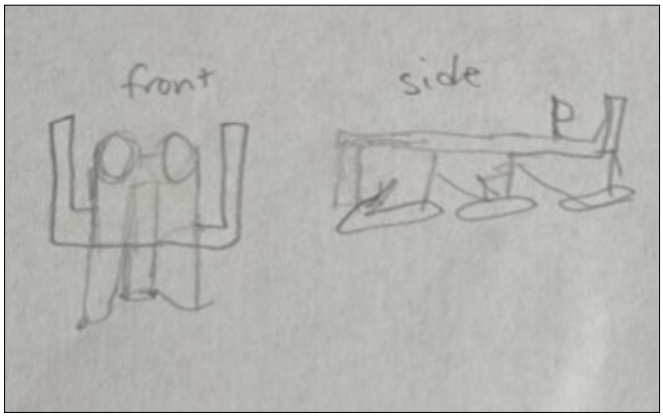


Figure 9. *Low visualizer orthographic sketch #3 (Sketch score: 8 points, Spatial score: 14%).*

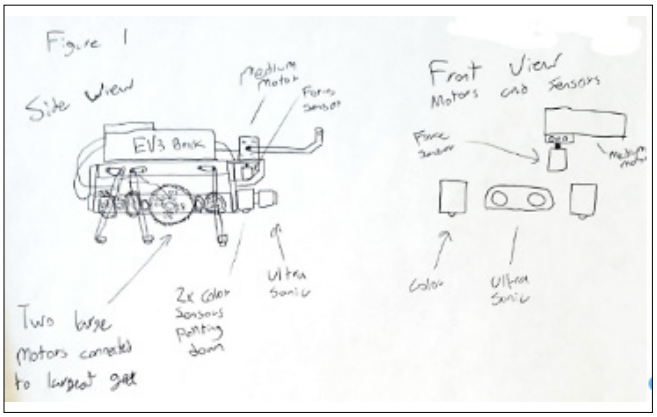


Figure 11. *High visualizer orthographic sketch #2 (Sketch score: 17 points, Spatial score: 75%).*

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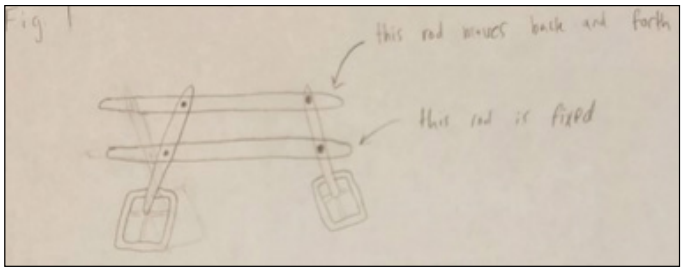


Figure 12. *High visualizer orthographic sketch #3 (Sketch score: 9.5 points, Spatial score: 92%).*

There is a noticeable discrepancy in quality and focus between Figures 10 and 12 when compared to Figures 11 and 13. Figures 11 and 13 follow a similar pattern of the low spatial visualizers' orthographic sketches with a single side orthographic view and labels to point out specific sensors and mechanisms; this is followed by one or more detail views on mechanisms of movement and lifting, similar to Figure 4 (low visualizer schematic sketch) that grouped information on a single sketch. A simplistic tally was conducted to count the occurrence of three key components of the sketches: callouts or annotations that describe elements of the sketch through text (e.g. a phrase or sentence detailing information, or front /side); labels that specify specific components, sensors, or object in the robot (e.g. ultrasonic sensor, lifting-mechanism); arrows or lines that indicate motion, direction, functions. Table 2 presents the tallies for the schematic and pictorial sketches, and Table 3 presents tallies for both groups of orthographic sketches.

Low spatial visualizers used more annotations, labels, and motion lines as part of their schematic

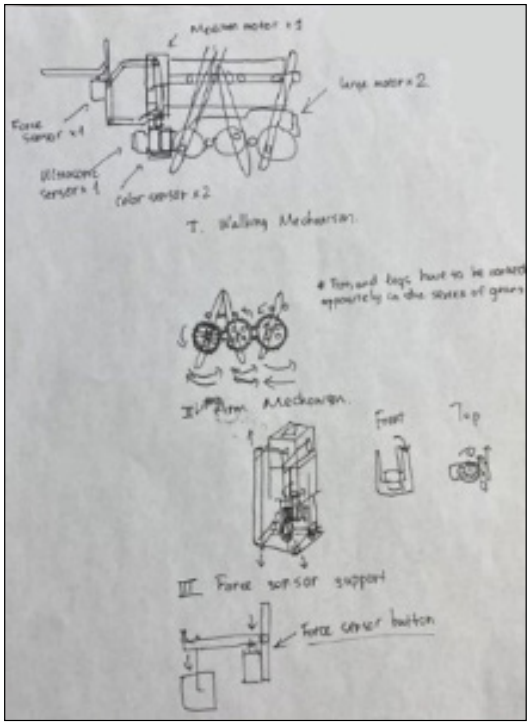


Figure 12. *High visualizer orthographic sketch #4 (Sketch score: 18 points, Spatial score: 99%).*

sketches to illustrate movement and task operations, with less focus on overall robotic appearance. Low spatial schematic sketches may have had less confidence in sketching the full robot, which would include aspects of lifting and leg mechanisms, and to compensate these participants relied on alternative ways to communicate information such as more annotations and labels. Conversely, high spatial visualizers generated pictorial sketches that used sparse labels and annotations and relied on a single 3D view of the robot to communicate information. The lo-

Table 2.
Schematic and pictorial sketch tallies.

Sketch Figure	Spatial Rank	Annotations/ Callouts	Labels	Motion Arrows/ Motion Lines	Total
Figure 3	Low	12	2	14	28
Figure 4	Low	5	5	3	13
Figure 5	High	0	2	0	2
Figure 6	High	1	2	0	3

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Table 3.
Orthographic sketch tallies.

Spatial Rank	Sketch Figure	Annotations/ Callouts	Labels	Motion Arrows/ Motion Lines	Total
Low	Figure 7	1	3	0	4
	Figure 8	0	6	2	8
	Figure 9	2	0	0	2
High	Figure 10	0	3	0	3
	Figure 11	4	8	0	12
	Figure 12	2	0	0	2
	Figure 13	3	6	15	24

cations of the legs and lifting mechanisms were clear, however the specifics of movement of the robot were difficult to derive. Further detail views or usage of movement lines or annotations could offset this; however these participants may have felt it necessary to only provide a single view. Participants' written responses may have driven the focus of sketches; low spatial visualizers may have wanted to communicate further details that were difficult to describe through textual mediums; whereas high spatial visualizers may rely on sketches to enhance their written report.

Larger variations were found in orthographic sketches within and between low and high spatial visualizers. For two of the three low orthographic sketches, general comprehension of movement and lifting of the robot could be derived, such as where the front was, sensor locations, some form of a claw or grip, and leg locations; labels and annotations were used for these sketches, with less reliance on motion lines. This was not the trend for all low orthographic sketches. High orthographic sketches were polarized, where Figures 10 and 12 focused only on a single detail view of the legs with annotations and labels, while Figures 11 and 13 focused on multiple aspects of the robot, with specific detail views which focused on sensors and used annotations to describe operations. Figure 13 notably utilized multiple arrows to convey movement and specific operations; this participant is likely strong in both spatial visualization and sketching skill.

Discussion of Results

In this research, low spatial visualizers, individuals who may have weaker mental visual imagery, often used more holistic and complex sketches with annotations to communicate information about their robot, whereas high spatial visualizers often only sketched portions of the robot. This could be interpreted as the low visualizers had to sketch out information they may not have been able to fully visualize, whereas the high visualizers only sketched information they felt important to point out, likely due to their stronger mental imagery of the robot. Previous literature has stated that individuals with difficulty recollecting complex mental imagery may rely on sketching to externalize designs and communicate information; conversely those that have stronger visual imagery rely on mental recollection and may opt not to sketch at all (Yang & Cham, 2007). Other confounding variables on the decision to produce a sketch involve self-perceived and actual drawing skills (2007).The data presented here does not support this notion 100%--some low spatial visualizers had poor sketch quality and sparse information, and two high spatial visualizers had more detailed sketches; however, this study lends more data to trends between spatial

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and sketching skills in engineering. Another result was the notable number of participants who opted not to generate any sketch at all (~59%). This may be due to recent trends where engineering students do not feel required to sketch as much (Marklin et al., 2013; Song & Agogino, 2004; Westmoreland et al., 2011) or due to a lack of prompts as prompts are important indicators of deciding to sketch (Rose, 2005; Weaver et al., 2024). This could explain why so many participants chose not to generate a sketch as they may have assumed the written document was enough and they weren't required to complete a sketch. These findings parallel the after-effects of some sketching interventions, where some participants that voiced concern about no mastery of sketching skills (Jeong, 2019), did not have long-term improvements in reducing their inhibition to generate sketches (Booth et al., 2016), and for students that did admit the sketching process does help with design, they maintained that design problems could be solved without needing to sketch (Schutze et al., 2003). Overall, the results from this research show a complex relationship between spatial and sketching skills, two very important skills for engineering students to master. Modern engineering students enter a curriculum that may progress spatial visualization skills naturally; this same curriculum has reduced the number of opportunities for freehand-sketching or replaced it with CAD or alternative software. Furthermore, the sketching opportunities in the curriculum are often more likely for specific majors, and with a growing number of engineering degrees in electrical, industrial, chemical, and software /computer engineering, the sparse opportunities for sketching may be reduced further for those majors. Such sketching opportunities may only be a workshop, intervention, or a few modules embedded in a larger course, often to aide or measure their spatial skills. This may reveal a self-limiting relationship between sketching and spatial skills, in which sketching skills are used by engineers to improve their spatial skills, but due to their heightened spatial skills, the engineers are then more likely to only utilize their superior spatial skills, reducing or completely removing their reliance on sketching.

Limitations and Future Work

This work used sketches that were collected as part of a larger written communication task that explored a team design project. Future work should consider making a mandatory question that asks participants to generate a sketch about their team design project. This work only examined the low and high visualizer sketches; future work will examine the medium visualizer sketches which contained a larger variation in sketch quality that necessitates an individual examination and discussion. This research was conducted with participants who successfully completed several spatial visualization training modules a semester prior, so they were likely more familiar with sketching. This may vary based on institutional curriculum. Each participant was part of a team in the prior semester, which was comprised of 3 to 4 participants with individual roles that may have consisted of a builder, project manager, documenter, or coder. Individual experiences might have obvious implications for what is remembered by the participant and may have impacted their resulting sketches; however, team role data was not collected. The participants were interviewed inside a room with a researcher in a one-on-one recorded setting which may have impacted scores or sketching capability. Participant's standardized test scores were not collected but these could provide further insights into characteristics about engineers who opt to sketch. This work was conducted as part of larger research study that examines how spatial skills are related to various communication skills. Future work will examine how the sketching communication discussed in this can interact with the written and oral communication of participants and further discuss implications that those interactions may have.

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Conclusions

This research examined relationships between spatial skills and sketching skills, two important This research examined relationships between spatial skills and sketching skills, two important proficiencies for an engineer. Participants consisted of a variety of engineering majors in a first-year engineering course who had all practiced spatial visualization and sketching the semester prior. Participants completed spatial visualization tasks and an optional sketching task that described the robot their team generated in the prior semester. Results revealed variations within sketches by spatial rank, with some low visualizers generating more comprehensive sketches that showed tasks or overall pictures of the robot, whereas some high spatial visualizers opted for specific aspects of the robot to sketch. However, these sketches were generated in tandem as written reports of their robotic projects, which likely influenced information participants decided to sketch. These results reinforce prior research that hypothesized that individuals with strong mental visualization skills may not want or need to generate sketches, as information is already available in their mind; conversely, low mental visualization ability may lead a participant to sketch more in order to have information in front of them to be able to think through their writing. Similar research should be conducted between spatial and sketching skills with the suggestions and limitations discussed in this research in mind to ensure more sampling opportunities and stronger representations of spatial visualization ranks.

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References

Booth, J. W., Taborda, E. A., Ramani, K., & Reid, T. (2016). Interventions for teaching sketching skills and reducing inhibition for novice engineering designers. *Design Studies*, 43, 1–23. https://doi.org/10.1016/j.destud.2015.11.002

CEEB. (1939). *Special aptitude test in spatial relations.*

Goldschmidt, G. (2007). To see eye to eye: The role of visual representations in building shared mental models in design teams. *CoDesign*, 3(1), 43–50. https://doi.org/10.1080/15710880601170826

Ishak, I., Ahmad, M. Z., Ismail, N., & Musa, A. R. (2012). *Environmental Factors Influencing Sketching Behaviour among Mechanical Engineering Undergraduates* (Y. Yusof & F. Phang, Eds.; Vol. 56, pp. 758–766). (WOS:000342616700088). https://doi.org/10.1016/j.sbspro.2012.09.713

Jeong, S. (2019). Case study: Effectiveness of a sketch learning model for engineering students. *Journal of Mechanical Science and Technology*, 33(12), 5721–5730. (WOS:000504965100015). https://doi.org/10.1007/s12206-019-1115-2

Lane, D., & Sorby, S. (2022). Bridging the gap: Blending spatial skills instruction into a technology teacher preparation programme. *International Journal of Technology and Design Education*, 32(4), 2195–2215. https://doi.org/10.1007/s10798-021-09691-5

Loney, N., Duffy, G., & Sorby, S. (2019). The Relationship Between Spatial Skills and Solving Problems in Chemical Engineering. *2019 ASEE Annual Conference & Exposition Proceedings*, 33419. https://doi.org/10.18260/1-2--33419

Marklin, R. W., Jr., Goldberg, J. R., Nagurka, M., & ASEE. (2013). *Freehand Sketching for Engineers: A Pilot Study*.

Copyright 2026 ISSN:
1949-9167

(WOS:000367454806028). 2013 ASEE Annual Conference.

McGown, A., Green, G., & Rodgers, P. A. (1998). Visible ideas: Information patterns of conceptual sketch activity. *Design Studies,* 19(4), 431–453. https://doi.org/10.1016/S0142-694X(98)00013-1

Newcombe, N. S., & Shipley, T. F. (2015). Thinking About Spatial Thinking: New Typology, New Assessments. In J. S. Gero (Ed.), *Studying Visual and Spatial Reasoning for Design Creativity* (pp. 179–192). Springer Netherlands. https://doi.org/10.1007/978-94-017-9297-4_10

Raju, G., & Sorby, S. (2024). The Role of Spatial Skills and Sketching in Engineering Design Problem Solving. *2024 ASEE Annual Conference & Exposition Proceedings*, 48133. https://doi.org/10.18260/1-2--48133

Ramey, K. E., & Uttal, D. H. (2017). Making Sense of Space: Distributed Spatial Sensemaking in a Middle School Summer Engineering Camp. *Journal of the Learning Sciences*, 26(2), 277–319. https://doi.org/10.1080/10508406.2016.1277226

Rose, A. (2005). Graphical communication using hand-drawn sketches in civil engineering. *Journal of Professional Issues in Engineering Education and Practice*, 131(4), 238–247. (WOS:000232185300006). https://doi.org/10.1061/(ASCE)1052-3928(2005)131:4(238)

Schmidt, L. C., Hernandez, N. V., & Ruocco, A. L. (2012). Research on encouraging sketching in engineering design. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, 26(3), 303–315. https://doi.org/10.1017/S0890060412000169

Shea, D. L., Lubinski, D., & Benbow, C. P. (2001). Importance of assessing spatial ability in intellectually talented young adolescents: A 20-year longitudinal study. *Journal of Educational Psychology*, 93(3), 604–614. https://doi.org/10.1037/0022-0663.93.3.604

Song, S., & Agogino, A. M. (2004). Insights on designers' sketching activities in new product design teams. *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, 46962, 351–360. https://asmedigitalcollection.asme.org/IDETC-CIE/proceedings-abstract/IDETC-CIE2004/46962a/351/306264

Sorby, S. A. (2007). Developing 3D spatial skills for engineering students. *Australasian Journal of Engineering Education*, 13(1), 1–11.

Sorby, S. A. (2009). Educational research in developing 3-D spatial skills for engineering students. *International Journal of Science Education*, 31(3), 459–480.

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: A meta-analysis of training studies. *Psychological Bulletin*, 139(2), 352.

Vandenberg, S. G., & Kuse, A. R. (1978). Mental Rotations, a Group Test of Three-Dimensional Spatial Visualization. *Perceptual and Motor Skills*, 47(2), 599–604. https://doi.org/10.2466/pms.1978.47.2.599

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology,* 101(4), 817–835. https://doi.org/10.1037/a0016127

Weaver, M. B., Ray, S., Hilton, E. C., Dorozhkin, D., Douglas, K., Hammond, T., & Linsey, J. (2022). Improving engineering sketching education through perspective techniques and an AI-based tutoring platform. International *Journal of Engineering Education*, 38(6). https://par.nsf.gov/biblio/10405700

Westmoreland, S., Ruocco, A., & Schmidt, L. (2011). Analysis of Capstone Design Reports: Visual Representations. *Journal of Mechanical Design*, 133(5), 051010. https://doi.org/10.1115/1.4004015

Copyright 2026 ISSN: 1949-9167

Yang, M. C., & Cham, J. G. (2007). An Analysis of Sketching Skill and Its Role in Early Stage Engineering Design. *Journal of Mechanical Design*, 129(5), 476–482. https://doi.org/10.1115/1.2712214

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Appendix

Appendix A. Orthographic Sketch Rubric

Phase 2 Sketching Rubric Version

Student Identification #: _____ Evaluator: _____

For the following questions, please review the sketch of the student and respond to the prompts using the Likert scale (1-6). For each question, please provide comments on why you chose the score and any other information in the white box below each bulleted list.

1. Overall robotic sketch

1	2	3	4	5	6
Unacceptable	Marginal	Adequate	Above average	Strong	Exceptional
• From a single sketch can the operation of the robot be determined? • Is the general form of robot comprehendible? • Can you derive a clear purpose of the robot from the full sketch alone (not detail views)					

2. Detail views of the robotic sketch

1	2	3	4	5	6
Unacceptable	Marginal	Adequate	Above average	Strong	Exceptional
• Are there multiple sketches that highlight specific details of the overall robot and operations / tasks it had to complete? • Are there multiple perspectives of the detail views (side / front / bottom) and are they consistent with the overall robotic form? • Do the detail views add or remove from overall understanding of the sketch?					

3. Callouts, annotations, and labels of sketch

1	2	3	4	5	6
Unacceptable	Marginal	Adequate	Above average	Strong	Exceptional
• Are there specific figure labels, titles, and callouts to clarify information about the robot? • Do callouts reference other detail views / overall sketch? • Is motion, direction, function shown with arrows or other annotations?					

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• Are the callouts and text information necessary to clarify key elements of the sketch?

4. Line proportionality, consistency, and accuracy

1	2	3	4	5	6
Unacceptable	Marginal	Adequate	Above average	Strong	Exceptional
• Is the weight of the lines consistent, or does weight change in a purposeful manner to show more depth or detail? • Are lines repeatedly drawn / hashed together or are they smoother? • Do lines maintain similar proportion or are they randomly drawn / erratically placed in the sketch?					

5. Sketch perspectives, dimensions, and form

1	2	3	4	5	6
Unacceptable	Marginal	Adequate	Above average	Strong	Exceptional
• Is the sketch in 2D, 2.5D, or 3D form? • If the sketch has detail views, are they consistent in the form and can they be spatially connected? (e.g., are the leg amounts consistent / in the same location) • Do detail views, callouts, and the full robotic sketch logically fit together?					

Appendix B. Intraclass Correlations

Model	Type	Unit	ICC_Estimate	CI	P-value
oneway	agreement	single	ICC(1) = 0.851	0.791 – 0.896	p = 7.26e-33
oneway	agreement	average	ICC(2) = 0.920	0.883 – 0.945	p = 7.26e-33
twoway	agreement	single	ICC(A,1) = 0.851	0.790 – 0.896	p = 1.63e-32
twoway	agreement	average	ICC(A,2) = 0.920	0.883 – 0.945	p = 1.62e-32
twoway	consistency	single	ICC(C,1) = 0.850	0.789 – 0.895	p = 1.80e-32
twoway	consistency	average	ICC(C,2) = 0.919	0.882 – 0.945	p = 1.80e-32

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Appendix C. Orthographic Descriptive Statistics (n=22) (one female participant did not disclose status)

Spatial Rank	**Male**		**Female**	
	Domestic	*International*	*Domestic*	*International*
Low	2	0	2	0
Medium	5	5	4	0
High	2	1	0	0

Appendix D. Schematic Descriptive Statistics (n=7)

Spatial Rank	**Male**		**Female**	
	Domestic	*International*	*Domestic*	*International*
Low	0	1	1	0
Medium	1	1	2	1
High	0	0	0	0

Appendix E. Pictorial Descriptive Statistics (n=6)

Spatial Rank	**Male**		**Female**	
	Domestic	*International*	*Domestic*	*International*
Low	0	0	0	0
Medium	2	2	0	0
High	1	1	0	0

Appendix F. Normality tests for data for spatial scores

Group	Shapiro-wilk	Skewness	Kurtosis
Orthographic	W = 0.945, p = 0.245	-0.331	-0.594
Schematic	W = 0.935, p = 0.597	-0.077	-1.086
Pictorial	W = 0.901, p = 0.38	0.653	-0.906