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# More Than Paper Cranes: A STEAM-Based Approach to Teaching the Engineering Design Process Through Origami (Work In Progress)

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## Abstract

This work in progress paper examines how early intervention programs are critical for introducing elementary school students to engineering concepts. To be effective, these programs need to employ engaging methods to attract students to the field and its core principles. This paper details an innovative, hands-on STEAM workshop for first to fifth-grade students that utilizes the art of origami to teach the engineering design process and problem-solving skills. By utilizing inexpensive and universally accessible materials, such as paper, this workshop offers an equitable framework for advancing K-5 engineering education, which can be implemented in any setting, regardless of budgetary constraints.

Participants were introduced to fundamental origami techniques, which inherently enhance skills such as spatial reasoning, attention to detail, patience, and perseverance. These enhanced skills serve as a scaffold for introducing students to the formal engineering design process: Ask, Imagine, Plan, Create, and Improve. Students apply this process to solve age-appropriate challenges using their innovative origami creations. The findings in this study are based on qualitative classroom observation and students' stories about each design they create.

These initial findings suggest high student engagement and a strong understanding of iterative design, shown by their willingness to refine their folded structures. This study will outline the curriculum, discuss preliminary results, and present the program as an effective model for integrating art into engineering education, thereby enhancing a more creative generation of problem solvers.



**Keywords:** Origami, STEAM, Engineering Design Process, K-5, Curriculum


## Introduction

Early exposure to engineering education shapes how children conceptualize problem-solving and develop design efficacy [1-3]. When children have experience with engineering, they learn more than just technical skills. They also learn to be curious, persistent, flexible, and use their imagination [4, 5]. These skills are foundational to all professional practices that young learners need in their lives later. Some research show that students often lose important engineering skills they had as children. In fact, children naturally exhibit strong engineering behaviors, such as easily identifying problems and generating many ideas [6-9]. However, research shows that students often lose these innate skills over time. When students start their undergraduate engineering studies, they do not demonstrate the creative behaviors they had as children [10, 11]. Elementary schools try to include engineering in K-5 classrooms. However, they still find it difficult to make engineering understandable and suitable for young students [7, 9, 12].

One ongoing challenge in teaching engineering to young students is helping them understand the engineering design process through different tools and ways [13, 14]. The engineering design process is at the center of engineering, as research shows in this field [1]. Researchers have tried to provide comprehensive frameworks that are suitable for this age [15, 16]. Frameworks like Ask, Imagine, Plan, Create, and Improve can be helpful to teach children. If they do not get hands-on, playful experiences with design, engineering might just become another task on a checklist rather than a fun practice of exploration and improvement [5].

Integrating the arts into engineering education can be a promising way to address challenges in the field [17]. STEAM learning environments focus on creativity, visual judgment, and hands-on learning. These environments can allow students to connect with engineering ideas through different forms of expression [18]. One of these art tools that helps students improve their creativity and hands-on learning is origami. Origami, a traditional paper-folding art, can provide valuable teaching opportunities [19]. Different studies show that origami can help students develop spatial thinking skills, attention to detail, patience, and the ability to try again when creating something [20, 21]. Origami requires few materials and is an inexpensive tool in education. These qualities make origami particularly suitable for fair use in various elementary school settings.

Furthermore, origami is inherently aligned with key parts of the engineering design process. Each fold represents a design choice, and each mistake offers a chance to correct it. Children can evaluate and improve their structure even after they finish. By folding and refolding, students learn iteration, which is an important part of making things work. These attributes show origami can connect artistic creation and engineering design thinking.

This work-in-progress paper presents a hands-on STEAM program designed for first through fifth-grade students that uses origami as a tool for teaching the engineering design process. The program introduces students to foundational origami techniques and then explicitly connects these practices to the stages of asking, imagining, planning, creating, and improving. Students apply this process to solve age-appropriate engineering challenges using their origami creations, engaging in cycles of testing, reflecting, and redesigning. Using a qualitative approach, this study draws on classroom observations and students' narrative explanations of their designs to examine how learners engage with the engineering design process through origami as part of their solutions.

**Guiding framework**

The design of this program is grounded in two pedagogical domains: Constructivist learning theory and the philosophy of strange tools. These theories informed the instructional strategies used to teach the Engineering Design Process (EDP) to learners at the elementary school level.

The program's instructional approach relies on cognitive and social constructivist theories. Specifically, the curriculum of this workshop utilizes Jean Piaget's (1953) concept of accommodation to develop the learning drive. Accommodation occurs when a learner's existing mental model fails to solve a new problem, compelling them to adjust their thinking. In this program, this cognitive shift is triggered by material resistance [22, 23]. When a student's first plan for folding paper does not hold weight, they experience "uncertainty" and need to change their understanding of the material to continue. Additionally, the program incorporates Vygotsky's Social Constructivism [24]. Learning is viewed as a social process facilitated by interaction [25]. The instructor does not act like a traditional teacher but as a guide. They provide support to help students stay within their Zone of Proximal Development (ZPD)[24]. This support allows students to attempt complex engineering tasks that would be too difficult to complete independently. Moreover, this workshop uses origami as a 'strange tool' to improve creative engagement. In everyday language, a tool is a physical object, like a ruler. However, based on Alva Noë's philosophy, strange tools also encompass artistic practices and processes that interrupt routine thinking [26]. In this program, origami functions as a pedagogical tool rather than a physical instrument. While the physical material is simply paper, the practice of folding it acts as a mechanism that forces students to pause, negotiate with the material, and explore structural geometry in new ways

**Program Description**

The program was implemented as an informal after-school program at a public school in the Midwest USA. The program ran for three weeks, consisting of one 70-minute session per week. In the first week, students learned basic folds in origami, such as mountain and valley folds, to improve their manual skills. In the second week, they connected origami actions to the Engineering Design Process, such as linking unfolding to improvement. In the third week, the program concluded with the "Bridge Emergency" challenge, in which students had 15 minutes to sketch their ideas and 45 minutes to build a bridge with a 10-inch span that could hold a 3oz load. The learning objectives of the program include:

- Define and describe the definition of origami at the elementary level.
- Create and design at least three origami structures fully and without the teacher's help.
- Analyze designs in the class after completing the activities for their teacher and peers.
- Define who an engineer is and what they do.
- Describe the engineering design process and how it can help to solve engineering problems.
- Solve open-ended problems during engineering activities by following the design process.

To evaluate the program, the final engineering activity was used for this study. The bridge challenge was used to evaluate the program's effectiveness. Students completed an individual design challenge titled "Help! We have a bridge emergency." A scenario was presented where the mayor needed a bridge to connect the two sides of a town. Strict constraints were applied to force engineering decision-making: 1) The bridge had to span 10 inches. 2) It had to support a specific weight (3 fl. oz box). 3) It could not be taped to the table. Students were provided with limited materials: origami paper, cardstock, clips, string, straw and tape. The session consisted of 15 minutes for planning (sketching) and 45 minutes for construction.

**Research Design**

Five participants (3 females and 2 males) attended the program and participated in the bridge activity. This study used an exploratory multiple-case study method to understand how students solve problems. The first author from the research team analyzed the data using a mixed coding approach. To ensure rigor, the researcher conducted multiple read-throughs of the field notes and listened to the audio recordings repeatedly to gain a holistic understanding of each student's process. During the first coding cycle, deductive codes based on Runco's [27] Divergent Thinking framework were applied to identify examples of fluency, flexibility, originality, and elaboration. In the second cycle, inductive codes were generated and then collapsed into broader themes regarding how students engaged with materials and responded to challenges.

Because the study utilized multiple data sources, they were analyzed in a complementary manner to build a complete narrative. There was high concordance across the datasets; each source added a necessary layer to the full story. The field notes captured the physical steps and struggles students experienced; the audio recordings provided the engineering rationale for those decisions; and the physical artifacts offered tangible proof of the final structures. The research team ensured the trustworthiness of the findings by triangulating these three complementary sources.

## Findings

Observations from the Bridge Emergency challenge indicated that origami acted as a low-risk medium for experimentation. Unlike usual materials such as wood or plastic, which require time-consuming reconstruction after failure, paper enables quick iteration. The data revealed three primary themes: *facilitating the "Improve" phase*, *applying structural reasoning*, and *translating origami into structural solutions*. These themes emerged directly from triangulating the data sources. For instance, evidence for the 'Improve' phase was primarily captured through field notes tracking material failures, while 'structural reasoning' was supported by the audio recordings of students explaining the geometry of their final artifacts.

### *Facilitating the "Improve" Phase*

A key finding of the program was that students learned to improve their solutions when their first attempts did not work. In regular classrooms, failures often frustrate students [20, 21]. This frustration usually comes from strict time limits and graded assessments. Because this study happened in a low-stakes after-school setting, it removed those pressures. The relaxed environment, along with the low cost and easy changes of folded paper, helped students feel less afraid of failing. Instead of getting upset, students use origami to quickly adjust their strategies. For example, Student A (Grade 3) found out during construction that one sheet of paper was too short to cover the 10-inch gap. If the student had been using stiff materials like wood or plastic, this mistake usually would have meant throwing away the piece and starting over with a longer material. However, since paper is flexible, the student could quickly move to the 'Improve' phase without wasting any resources. Instead of asking for new materials, the student folded two separate sheets into beams and connected them to create one longer piece. This shows how the flexibility of paper allows students to easily fix problems in ways that stiff materials do not allow.

Similarly, Student B (Grade 4) first tried to build bridge legs using bundled straws. When the straws were too slippery to tape together, they moved away from that material but kept the goal of building a structure. Referring to the program's geometry lessons, they switched to folding paper into triangular prisms, saying they needed a "strong shape." This shows how the flexibility of paper allowed them to fail without high stakes and redesign their project right away.

### *Application of Structural Reasoning*

Students showed their ability to turn abstract geometric ideas into physical structures that can hold weight. Student C (Grade 3) gave the clearest example of this. They noticed that simple cylinder legs were not stable, so they changed to a "fortune teller" [28] fold, a childhood game taught in the program, into a bridge landing. They explained their engineering reasoning for this well: "Triangles are stronger than circles." By turning a fortune teller into a structural base, they demonstrated a strong understanding of how geometric folding can strengthen structures.

### *Translating Origami into Structural Solutions*

Four students used origami to create unique and strong bridges. They did not see paper as just flat but shaped it to form functional parts. For example, Student D (Grade 4) twisted thin strips of paper into cables, saying they felt like a "hard rope" to support their bridge's legs. Student B built a multi-level bridge with two parallel roads, folding and interlocking thick sheets of paper to make a strong beam that could safely cover the needed distance. The students used familiar origami shapes to solve structural problems. For example, Student C, who used a fortune teller for their bridge legs to make them stable, or Student D, who made a bridge like a fish.

Student E (Grade 5) had a more traditional view of engineering. They decided not to use origami and instead built a typical post-and-beam structure with plastic straws for the legs and flat, unfolded paper for the roof. The interview showed that they did not want to use paper folding because it did not match what they observed in the real world. They said that their straw legs looked "like bridges in …." and questioned paper structures, saying, "I have never seen any bridges with origami." However, when their flat paper road started to sag under the weight, they still used the program's main lesson about manipulating materials. They tightly wrapped another sheet of paper around the road and straw supports, explaining that they did this "to protect it from bending." This shows that while some students stick to materials and shapes they see in real life, they still understand the key idea of reinforcing materials to support weight.

## Discussion

The data from this pilot program demonstrates that origami is a uniquely effective medium for teaching the engineering design process. By using paper folding as a foundational tool, the program succeeded in three critical areas of engineering education: reframing failure, promoting deep material engagement, and providing equitable access to complex design tasks.
Origami changes how students handle design failures. In engineering projects for young learners, material failure can cause frustration and disengagement because rigid materials take time to fix [7]. However, as shown by Student A and Student B, the flexibility of paper allows them to see failure as a temporary challenge that is easy to fix. When Student A's paper was too short, they just folded and connected two sheets instead of throwing the material away. When Student B found the straws too slippery, they quickly switched to folded paper prisms. This shows that origami supports the "Improve" step of the Engineering Design Process (EDP). It creates a safe

environment where students can quickly prototype and try again without worrying about wasting expensive materials [29].

Moreover, in this study, using strange tools helped students engage deeply with materials. Noë [26] points out that unusual tools like these break habitual thinking, making users focus more on the material. In this study, students had to see paper not just for writing but as a building material. One third-grade student noted that “triangles are stronger than circles,” showing how folding helped them turn abstract geometry into real engineering understanding. This supports recent research by Marji et al. [20], which found that activities like origami improve spatial reasoning and structural understanding in STEM subjects. The unique nature of the tool discouraged standard building practices; instead, it encouraged students to work with the material’s physics, resulting in deeper insights about weight distribution and strength, which are rare in typical elementary classrooms.

The evidence from this pilot study suggests the potential for making materials accessible for fair engineering education. Many STEAM programs use expensive robotics kits or 3D printers, which can create a gap between well-funded schools and those with fewer resources [5]. However, this program achieved complex engineering learning using just easily accessible materials such as paper and tape. The creative solutions students came up with proved that advanced engineering thinking does not need high-tech tools. This supports idea that using low-cost, arts-based materials can make engineering education more available to everyone [17]. By showing that students can use easily available materials for high-level design thinking, this program provides a model for teaching engineering to different groups of students, ensuring that financial issues cannot stop them from developing important problem-solving skills.

## Conclusion

The Origami & Engineering Design program demonstrates that integrating arts-based tools into STEM curricula can enhance students’ understanding of the engineering design process. By navigating the physical constraints of paper, students learned to plan, test, and improve their ideas, developing the foundational habits of mind required for future engineering success.

First, origami is very affordable and easy to access, which removes financial barriers for schools wanting to adopt hands-on engineering programs. Second, paper is easy to reshape, so students do not fear making mistakes. They can quickly fold and unfold their work, allowing them to learn and improve without frustration. Third, origami helps students connect math with science; they see how changing the shape of a material (like folding a flat sheet into a triangular prism) increases its strength. Overall, using origami in the classroom is more than just an art project. It is a practical, low-pressure way to teach engineering that gives students the resilience, spatial awareness, and problem-solving skills they need to become future innovators.

## References

[1] E. Sung and T. R. Kelley, "Elementary students’ engineering design process: How young students solve engineering problems," *International Journal of Science and Mathematics Education,* vol. 21, no. 5, pp. 1615–1638, 2023.

[2] National Academies of Sciences, Engineering and Medicine, *Building capacity for teaching engineering in K-12 education*. National Academies Press, 2020.

[3] K. Eason, W. Gaskins, B. Guy, S. Martin, and S. Askarian, "We lose the game before we start to play: How Black women make meaning of their experiences in engineering education," *Journal of Black Excellence in Engineering, Science, & Technology,* vol. 1, 2023.

[4] D. Pusca and D. O. Northwood, "Curiosity, creativity and engineering education," *Global Journal of Engineering Education,* vol. 20, no. 3, pp. 152–158, 2018.

[5] A. S. Bustamante, D. B. Greenfield, and I. Nayfeld, "Early childhood science and engineering: Engaging platforms for fostering domain-general learning skills," *Education Sciences,* vol. 8, no. 3, p. 144, 2018.

[6] A. Bagiati and D. Evangelou, "Practicing engineering while building with blocks: Identifying engineering thinking," *European Early Childhood Education Research Journal,* vol. 24, no. 1, pp. 67–85, 2016.

[7] E. Meintel, S. A. Khanamani, B. M. Bartish, W. Gaskins, and K. Turner, "Draw an engineer," in *2024 ASEE Annual Conference & Exposition*, 2024.

[8] W. Gaskins, S. Askarian, and K. Eason, "Black is gold: the importance of racial identity to black undergraduate students in engineering," in *2022 ASEE Annual Conference & Exposition*, 2022.

[9] H. Ehsan, A. P. Rehmat, and S. Askarian Khanamani, "Developing STEM wisdom in neurodiverse gifted learners: an asset-based approach to engineering design for autistic children," *Roeper Review,* vol. 48, no. 1, pp. 51–62, 2026.

[10] C. J. Atman, R. S. Adams, M. E. Cardella, J. Turns, S. Mosborg, and J. Saleem, "Engineering design processes: A comparison of students and expert practitioners," *Journal of Engineering Education,* vol. 96, no. 4, pp. 359–379, 2007.

[11] A. M. Johnson, S. A. Khanamani, M. O. Onyango, and W. Gaskins, "Board 179: Campus climate, STEM students: examining structural obstacles for BW student success," in *2024 ASEE Annual Conference & Exposition*, 2024.

[12] R. Hammack and T. Ivey, "Elementary teachers' perceptions of K-5 engineering education and perceived barriers to implementation," *Journal of Engineering Education,* vol. 108, no. 4, pp. 503–522, 2019.

[13] P. S. Lottero-Perdue, "Engaging young children in engineering design: Encouraging them to think, create, try and try again," in *STEM in early childhood education*: Routledge, 2019, pp. 99–117.

[14] S. A. Khanamani, A. M. Johnson, M. Onyango, and W. B. Gaskins, "WIP: STEM culture from faculty perspectives: How faculty see climate in STEM and its effect on the sense of belonging of traditionally/historically excluded students," in *2024 IEEE Frontiers in Education Conference (FIE)*, 2024: IEEE, pp. 1–4.

[15] T. J. Moore, A. W. Glancy, K. M. Tank, J. A. Kersten, K. A. Smith, and M. S. Stohlmann, "A framework for quality K-12 engineering education: Research and development," presented at the ASEE Annual Conference & Exposition, 2014.

[16] R. S. Adams and C. Atman, "Characterizing engineering student design processes: An illustration of iteration," in *2000 Annual Conference*, 2000, pp. 5.143.1–5.143.11.

[17] K. Pleasants, "Integrative approaches in education: Bridging STEM and the arts," *Xpertno International Journal of Interdisciplinary Research (XIJIR),* vol. 1, no. 1, pp. 30–42, 2023.

[18] H. Thuneberg, H. Salmi, and F. X. Bogner, "How creativity, autonomy and visual reasoning contribute to cognitive learning in a STEAM hands-on inquiry-based math module," *Thinking Skills and Creativity,* vol. 29, pp. 153–160, 2018.
[19] T. Kraav and A. Rudanovski, "Educational origami: The design and implementation of the course 'Mathematical paper folding' in upper secondary school," in *International Meeting on Origami in Science, Mathematics and Education*, 2024: Springer, pp. 413–426.
[20] M. S. Marji, N. A. C. Derasid, A. H. Musta'amal, and A. A. Jobin, "Origami as an educational tool and its effect on the development of school students," *Jurnal Scientia,* vol. 12, no. 02, pp. 2011–2018, 2023.
[21] S. Cakmak, M. Isiksal, and Y. Koc, "Investigating effect of origami-based instruction on elementary students' spatial skills and perceptions," *The Journal of Educational Research,* vol. 107, no. 1, pp. 59–68, 2014.
[22] R. S. Siegler, *Emerging minds: The process of change in children's thinking*. Oxford University Press, 1998.
[23] S. Robson, *Developing thinking and understanding in young children: an introduction for students*. Routledge, 2012.
[24] L. S. Vygotsky, *Mind in society: The development of higher psychological processes*. Harvard University Press, 1978.
[25] J. Xi and J. P. Lantolf, "Scaffolding and the zone of proximal development: A problematic relationship," *Journal for the Theory of Social Behaviour,* vol. 51, no. 1, pp. 25–48, 2021.
[26] A. Noë, *Strange tools: Art and human nature*. Macmillan, 2015.
[27] S. Acar and M. A. Runco, "Divergent thinking: New methods, recent research, and extended theory," *Psychology of Aesthetics, Creativity, and the Arts,* vol. 13, no. 2, pp. 153–158, 2019, doi: https://doi.org/10.1037/aca0000231.
[28] Y. Wang and S. Perry, "Cootie catchers and fortune tellers: Folding creative origami play into critically analyzing and presenting qualitative research," *Departures in Critical Qualitative Research,* vol. 14, no. 3, pp. 55–83, 2025.
[29] B. L. Dorie, M. Cardella, and G. N. Svarovsky, "Capturing the design thinking of young children interacting with a parent," presented at the in 2014 ASEE Annual Conference & Exposition, Indianapolis, IN, 2014.