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Scaling Engineering Challenges for PK12 Outreach Programs (Other)

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Abstract

When developing engineering activities to teach engineering concepts for differentiated learning, the original activity is often modified to ensure it meets students' learning needs and abilities. Similarly, when providing engineering education in the precollege space, the curriculum often needs to be adapted to other grade levels and student abilities, including teacher professional learning offerings.

This paper outlines the process of scaling an engineering activity for different ages by utilizing examples from two case studies: a nanobugs and a self-folding shape engineering challenge. Both challenges were adapted for audiences ranging from K-2, 3-5, 6-8, 9-10, and 11-12 grade. These challenges were used both at week-long summer camps and short-duration outreach sessions with school groups. The nanobug challenge was also scaled for a teacher professional learning session. In both cases, the activities focus on the engineering design cycle and share engineering subject area content, but the activities themselves vary for each age group based on an array of design considerations and needs of each audience.

This paper includes a description of the content of the activities, observations from facilitators involved with the activities, and a discussion of the process by which the activities were modified for each age level. We outline steps that others can take to adapt hands-on engineering activities for audiences of different ages, such as adjusting complexity, modifying the constraints, modifying the criteria, adding a cost/material constraints, and supplementing the activity with scaffolding activities to ensure students have the skills necessary to understand the concepts (e.g. practicing 3-D spatial visualization skills).

Introduction

Our mission at The Engineering Place, a PK-12 Engineering Outreach Organization at the North Carolina State University College of Engineering, is to increase engineering access, awareness, and knowledge by engaging educators, K-12 students, parents, and the general public with innovative engineering education programming. We provide engineering education programs, resources, and experiences designed to spark curiosity, foster creativity, and build problem-solving skills while learning about math and science. Our initiatives include hands-on, open-ended PK-12 activities, professional development for teachers, and collaborations with all communities to ensure engineering is accessible and relatable for everyone. By connecting real-world challenges, many based on current research, with the engineering design process, we empower students and teachers to explore how engineering shapes our everyday lives and to envision themselves as creators of a better future. This paper explores how to use the differentiation strategy when designing engineering education outreach activities for informal learning environments. It provides several examples of differentiated engineering challenges and offers suggestions for how teachers and informal facilitators can tailor their own engineering activities.

Differentiation Instruction and Scaffolding

Differentiating engineering challenges increases the usability of developed challenges. Differentiated instruction (DI) is a teaching approach designed to meet students' diverse needs by matching educational experiences to their unique backgrounds, readiness levels, interests, and learning profiles[1,2]. Differentiated instruction is a part of the broader construct *differentiation*, which includes DI during a lesson and student assessment, evaluation, philosophical aspects, and more general principles.[3] DI focuses on adapting instruction to meet the needs of individual students since all learners do not have the same learning rate. By using assessment data to identify needs, strengths, and interests, teachers can design relevant and engaging learning experiences[4]. A characteristic of differentiation is using varied instructional strategies, such as direct instruction, cooperative learning, and hands-on activities.

Instructors most often differentiate their teaching by modifying one of the following: the content that learners learn, the process of how learners will learn it, and the final project. Teachers achieve this differentiation by modifying content, materials, or depth of coverage, employing diverse methods to help students make sense of information, and offering different ways for students to demonstrate learning, such as presentations, essays, or models. [2,4]

These strategies ensure that all students can access and engage with the content, aligning with Vygotsky's scaffolding theory, in which social interactions can guide a child's thinking toward solutions to problems, thereby helping the child master a new concept.[5] The zone of proximal development is known as the concept that a child can acquire new knowledge through guided participation with a teacher or a more capable person.[5] Scaffolding refers to the support provided by a teacher to help students accomplish tasks they could not complete independently, emphasizing adaptability to individual learning levels. Three key characteristics define effective scaffolding: contingency, which involves tailoring support based on diagnostic assessment of the learner's current competence; fading, the gradual withdrawal of assistance as the learner becomes more capable; and transfer of responsibility, where learners progressively assume control over their own learning. When working with younger learners, scaffolding supports in the way of exploratory activities or mini-lessons can provide the foundation for successful learning outcomes.[6]

The Engineering Design Process

All our programs integrate the engineering design process (EDP). The EDP is a series of steps engineers follow to find a solution to a problem.[7,8] The Engineering Place adapted the design process from the Museum of Science Boston's "Engineering is Elementary" program to include the following: ask, imagine, plan, create, and improve. This interactive framework begins with **Ask**, where we identify the problem, determine the design's purpose, and establish criteria for success and testing. Next is **Imagine**, where knowledge and creativity come together as teams brainstorm ideas, discuss possibilities, and select a solution to pursue. During the **Plan** stage, participants think critically about materials and resources, sketch detailed designs, and present their ideas for feedback. The **Create** stage involves building and testing the design and comparing results to the initial goals and expectations. Finally, in **Improve**, we analyze test results, identify the most impactful changes, and refine the design for better outcomes. This refinement, or iterative process, occurs throughout the entire cycle. EDP engages learners in active problem-solving and collaboration, emphasizing that learning and success come from testing, reflection, and adaptation.

Example 1: Nanobugs

The Nanobug Challenge was designed to highlight cyborg research at North Carolina State University. Researchers are exploring how far and fast cyborg cockroaches - or biobots - move when exploring new spaces. A cyborg is formed by the union of biology and technology[9]- in this case, cockroaches, which can be remotely controlled and carry technology that may be used to map disaster areas and identify survivors of natural disasters.[10] Before creating the biobots, researchers used hexbugs, known as nanobugs, to map large, unfamiliar areas, such as collapsed buildings, after a disaster. This challenge connects real-world engineering research with an engaging K-12 engineering activity for students.

The Nanobug Maze engineering challenge involves a hands-on, open-ended activity focused on the engineering design cycle using nanobugs. The activity was differentiated for multiple levels of learning since we conduct programs ranging from kindergarten to high school and teacher professional learning sessions.

The challenge begins by engaging and introducing students through an engagement activity. The engagement activity is differentiated based on the grade level. For example, the storybook *Bug Goes Through the Maze (Bug's Adventure Series)* by K. M. Groshek can be read to the PK-2 students to get them interested in the challenge. After reading the book, the challenge is introduced. For older students in grades 3-5, they could read the book themselves and discuss it together in preparation for the challenge. The story follows a Volkswagen Bug car as it travels through a maze. He meets new friends and has fun, but then gets nervous when he has trouble finding his way out. He refuses to give up and makes his way out of the maze. Using this bug maze idea, students are challenged to design a maze that a nanobug can navigate successfully with the most elements. For older students, instead of reading the storybook, we connected the scenario with something relevant in their lives, for example, a school garden. Their scenario could be as follows: Ms. Greenfield (principal name) wants to expand their school garden to add a pollinator garden to attract bees and other vital insects. Your team must plan and create a new garden design that allows a pollinator bug to travel around the garden. Your challenge is to design a garden maze that meets a series of design elements.

For younger students, scaffolding to help them successfully complete the challenge may involve focusing first on mini-challenges, such as making the nanobug move in a straight line, creating a tunnel or door, and making the bug traverse a ramp. Once students have mastered these exploratory activities, they can use their knowledge to create a maze using the mini-challenges as building blocks. For older students, these mini-challenges are not as explicitly provided but can be highlighted by teachers if groups struggle to break down the main engineering challenge of designing and building the maze. Differentiation between age groups for this activity occurs by providing different criteria for the maze. For example, K-2 students may be asked to create a maze with at least one turn, while students in grade levels 3-5 may be asked to create a maze with two turns, a tunnel, a loop, and a sound. In grades 6-8, students would be asked to include an incline and decline, a 90 and 360-degree turn, in addition to the other criteria. Another way to provide differentiation for older students is to allow students to "purchase" materials within a budget and receive points for extra elements in their maze. For high school students or teacher workshops, points assigned to each criterion add a competitive nature to the challenge. Table 1 shows how the nanobug maze challenge can be modified in each grade band. This tiered approach ensures that every student engages with the material meaningfully, fostering an understanding of STEM principles tailored to their level. This activity provides opportunities to integrate math and geometry (e.g., 90-degree, 360-degree turns, measuring different maze aspects), and science concepts (e.g., vibrating materials can make a sound).

Table 1: Nanobug Maze Challenge Differentiation

	PK-2 Grades	3-5 Grades	6-8 Grades	Teacher Learning Session
Changes in Criteria	• An entrance and an exit • A tunnel to go through • One left or right turn	• An entrance and an exit • A tunnel • One left and right turn • Sound • An obstacle for the bug to go around	• One entrance and one exit • 90-degree turn • 360-degree turn • Incline • Decline • Door	• 90-degree turn • 360-degree spin • Incline • Decline • Door • Completed Maze
Changes in Constraints		• Use only the listed materials • Run your bug through the garden without touching it. • The bug must enter and exit the maze. • If the bug is stuck, you may give it a nudge with your finger one time.	• Use only the listed materials • Run the nano bug through the playground without touching the bug or causing any outside interference. • If the bug is stuck, you may start over a maximum of 3 times. • The bug must exit the playground to receive 50 points.	• Use only the listed materials • Run the nano bug through the playground without touching the bug or causing any outside interference. • If the bug is stuck, you may start over a maximum of 3 times. • Points will be given based on the following parameters: 1. 90-degree turn – 10 pts 2. 360 degree spin – 40 pts 3. Incline – 40 pts/cm 4. Decline – 20 pts/cm 5. Door – 10 pts 6. Completed Maze – 50 pts 7. If touched – minus 5pts per touch

Example 2: Self-folding Shapes

The Self-folding Shapes activity was first developed by Dr. Michael Dickey at North Carolina State University as a broader impact on his research. Dr. Dickey's research focused on developing a simple way to convert two-dimensional (2D) patterns into three-dimensional (3D) objects using only light.[12] He applies printing patterns of ink on a pre-stressed polymer sheet, which shrinks in-plane by 50-60% when uniformly heated above 120 °C. Using a desktop printer, he patterns black ink, serving as hinges, on either side of the transparent sheets. These hinges selectively absorb light, heating the underlying polymer and triggering localized shrinkage, while the uninked polymer remains unaffected. Within seconds, the 2D patterned polymer sheets fold into complex 3D structures, such as cubes and tetrahedrons. Diagram 1, found in Appendix A, is the research poster describing this process. This was a novel application of existing materials and has the potential for rapid, high-volume manufacturing processes or packaging applications.[12]

The Engineering Place first tested and utilized the activity during a Summer Engineering Day Camp program. They introduced a scaffolding process by providing campers with pre-printed polymer pieces to cut out and place on a light table, where the pieces quickly folded into the desired shapes. Campers observed how the precision of their cuts affected the accuracy of the folding process. In the second part of the activity, participants designed and created their 2D shapes to experiment with how they folded into 3D forms.

We selected two middle school camps as a starting point to test the challenge and gather feedback on participants' overall interest in the topic, enjoyment of the process, and the activity's safety. During the sessions, we observed that some younger participants made random scribbles on their 2D shapes, then watched as the shapes crumpled into odd forms. After making minor adjustments—such as reducing the presentation time and providing more materials for campers to enhance their designs—we decided to scale the Self-folding Shapes activity to our upper elementary camp (rising 3rd–5th graders) and our high school day camp (rising 9th/10th graders).

For the elementary grades, we knew from observing the younger middle school campers that additional support would be necessary to help them understand the 2D-to-3D concept. To address this, we planned to spend time demonstrating how a flat 2D item could transform into a 3D shape. We introduced a step involving large, pre-printed paper copies of the designs used for the polymer, making them bigger and easier for campers to manipulate. They tried a few of these examples to see how items like a cube looked in their flat form before folding into 3D shapes and how a pyramid and the letters V and W transformed.

For the high school grades, we wanted to incorporate a real-world scenario that would give practicality and purpose to self-folding shapes. We created a scenario where students had to design a shape to package an object individually and automatically. Using items like marbles and dice, they determined the type of shape required to ensure proper packaging for their item.

After successfully implementing the activity with rising third through rising tenth graders, we decided to scale it to our rising K-2nd grade campers. We started with our plan for the upper elementary activity, but quickly realized we needed more time on the 2D-to-3D concept. To address this, we devised a plan to scaffold the activity using random boxes from around the house—such as cereal and pasta boxes—any box with glued seams that could be opened and flattened. We distributed the boxes to allow participants to construct and deconstruct the shapes. We also aimed to reinforce the idea that black is a good heat absorber. We selected several children from the group, each wearing a different color shirt, and had them stand in line. The remaining students then decided the order from left to right, ranking the colors from least to most hot on a summer day. The rest of the activity followed the same steps as the upper elementary version.

Overall, additional time consideration is needed for the exploratory scaffolding activities before beginning the Self-folding Shapes challenge for the younger participants to ensure they comprehend the challenge correctly. Table 2 highlights the exploratory activities and the differentiation of constraints.

Table 2: Self-folding Shapes Challenge Differentiation

	PK-2 Grades	3-5 Grades	6-8 Grades	9 - 10 Grades
Exploratory Activities	● Color line-up reinforcing how black absorbs more heat. ● Assemble and disassemble boxes. ● Using pre-printed paper, cut out and assemble a 3D shape. ● Practice cutting out various pre-printed shapes and see how well they perform.	● Using pre-printed paper, cut out and assemble a 3D shape. ● Practice cutting out various pre-printed shapes and see how well they perform.	● Practice cutting out various pre-printed shapes and see how well they perform.	● Practice cutting out various pre-printed shapes and see how well they perform.

Changes in Constraints	• Design a shape that will go from 2D to 3D when placed in the light device.	• Design a shape that will go from 2D to 3D when placed in the light device.	• Design a shape that will go from 2D to 3D when placed in the light device. • Create different types of options that close.	• Design a shape that will go from 2D to 3D when placed in the light device. • Design a shape that can be used to package an item. • Develop different packaging options, determine best option based on least amount of material measured by weight.

Results

We use the Nanobug and Self-Folding Shapes challenges at all age levels, both for short-duration 50-60 minute outreach events during the academic year and at our week-long Summer Engineering Camps. Our academic year programs include three types: 1) special on-campus events where one class of approximately 30 students comes to campus and participates in our 60-minute session as part of a full day's agenda of other activities (special events), 2) visits to schools where we spend the day providing engineering education sessions to classes throughout the day (Engineering on the Road), and 3) full-day events where up to 100 students come to campus and rotate between three or four different activities (Engineering Bits and Bytes). All these events average 50 minutes per session, and if the class has a tight schedule, including a student survey evaluation doesn't make sense. In the academic year program, we use formative assessment. These assessments involve listening to student interactions, asking them questions during the session, and having facilitators debrief after the event to suggest revisions for the next session, which are documented for future reference.

The week-long summer engineering camps allow for student surveys at the end of the week to capture their experiences. On Friday, campers complete a survey to provide feedback on all the activities, their feelings about staff members, their overall camp experience, whether they learned more about engineering, what they enjoyed, and suggestions for improvement. The survey collects both quantitative and qualitative data. The most relevant questions for this paper include those about the activities, what they enjoyed most, and how we can improve for next year. One survey question asks students, "How did you like all of the activities you did at camp?" with each engineering challenge listed. The Likert scale options are: I loved it, It was good, It was OK, I didn't like it, It was terrible. This same question is used for all grade levels.

Nanobug Challenges Survey Results

During the 2021 week-long virtual engineering camps for rising K-2, Elementary, and Middle School students, we used the Nanobug Challenge but renamed it Animal Park to align with the Amusement Park theme of the camp. While the constraints and criteria of the challenge remain the same, we revised the scenario and challenge problem based on the session goal and student group. The camps were held ½ days over Zoom. The same camp was offered in the morning and afternoon. Each session was 120 minutes and we had 19 rising K-2 campers, 54 rising elementary campers, and 134 middle school campers attend each week.

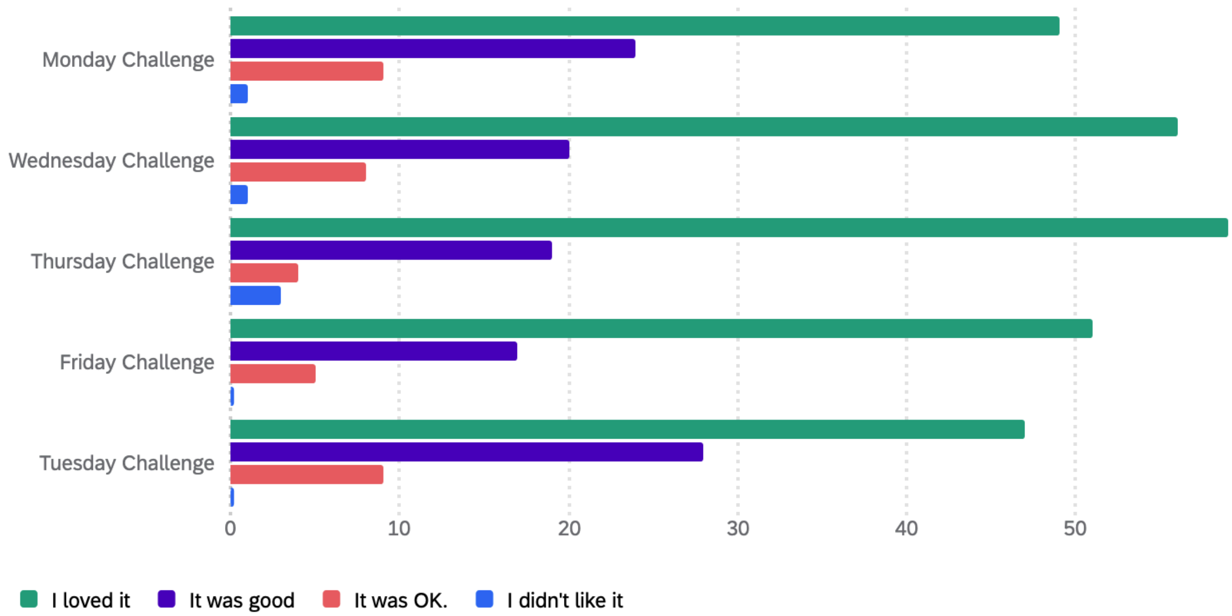
Rising K-2 Camp

The campers did not take a survey for this camp due to the challenges of completing an online survey from home.

Elementary Camp

The response rate ranged from 44 to 54 elementary students completing different survey sections. The Monday Challenge was an Amusement Park (the Nanobug activity), the Tuesday challenge was an Extreme Water Slide, Wednesday was a Bumper Car, Thursday was a Zip Line, and Friday was a redesign day. Table 3 indicates how the campers enjoyed the camp activities. The Nanobug activity was not the favorite activity, but it was also not the least favorite.

Table 3: How did you like all of the activities you did at camp? (Elementary Camp Responses)

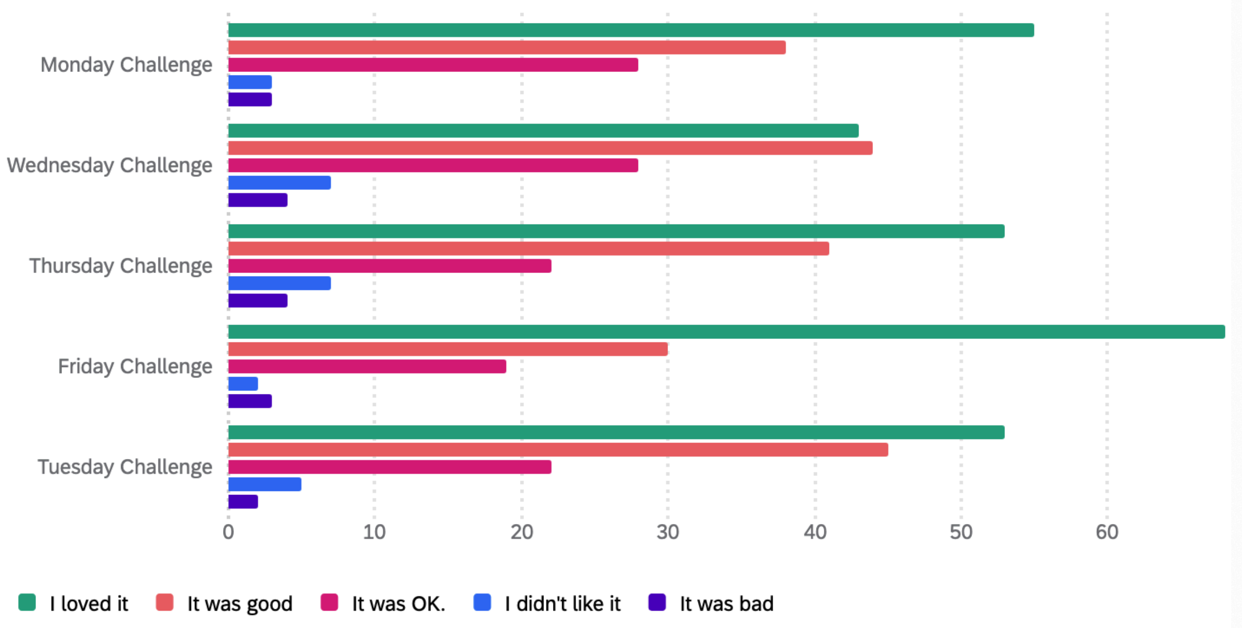


When asked what they enjoyed most about the week, there was a wide range of answers. Many stated that they enjoyed building and making the designs and the activities. One camper stated they liked “mondays project”. When asked what could be done to improve, most campers said nothing and they loved the camp. No one mentioned the nanobug challenge specifically.

Middle School Camp
134 middle school students completed the summer camp survey. The Monday Challenge was Amusement Park (the Nanobug activity), the Tuesday challenge was Extreme Water Slide, the Wednesday challenge was Bumper Car, the Thursday challenge was Ride-People-Mover Challenge, and the Friday challenge was Too Much, Too Little, and a Redesign Challenge. Table 4 indicates how the campers enjoyed the camp activities. The middle school students rated the Nanobug Challenge as their second favorite activity during the week.

When asked what the campers enjoyed most about the week, they provided a wide range of answers. Many mentioned their activities, enjoyment of building and making designs, and overall activities. One camper said they liked "Monday's project", the Nanobug activity. When asked what could be improved, most campers said nothing and expressed that they loved the camp. Table 4 indicates how the campers enjoyed the camp activities.

Table 4: How did you like all of the activities you did at camp? (Middle School Camp Responses)



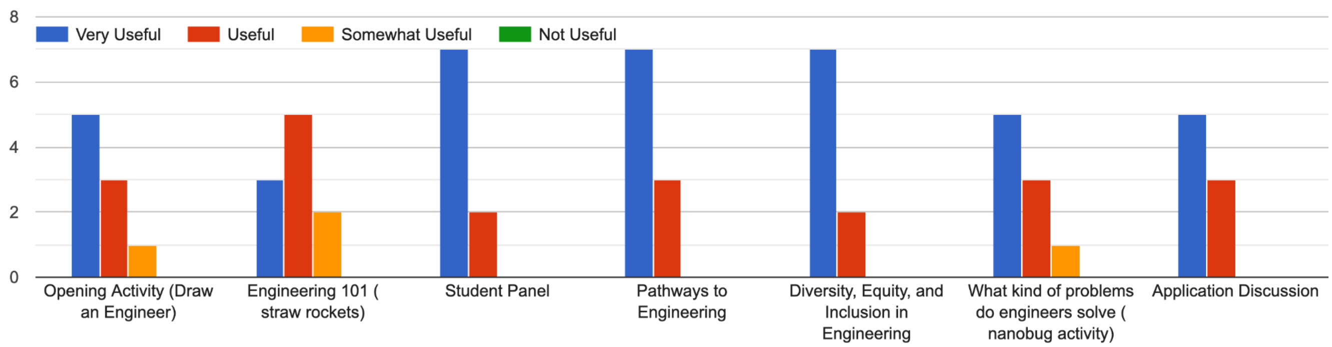
Teacher Professional Learning Results

We scaled the nanobug maze for adults for a professional learning experience for the NC State University's College Advising Corps (CAC) program, which we hosted. The NC State College Advising Corps is a nonprofit college access organization that aims to increase opportunities by making education beyond high school more accessible for students across rural North Carolina. Each year, nine recent North Carolina State University graduates serve as counselors in rural schools across the state. They undergo an intensive four-week training program each summer and receive ongoing training throughout the year to prepare them for advising high school students on college admissions and financial processes. We provided various sessions to increase the counselors' understanding of engineering, what it is, and who can do it. We wanted to offer them a hands-on engineering education challenge.

In scaling their experience, we increased their criteria, adding additional levels of complexity, and a point system was included during the testing session. We find it essential for teachers to actively engage and complete the activities and discuss how the challenge addresses state standards and how it could be modified for their classroom implementation. This follows research best practices, stating that when teachers engage in rehearsing or practicing lessons before delivering them to students, it can enhance their instructional effectiveness. This practice, often called "rehearsal,' allows teachers to refine their teaching strategies, anticipate student responses, and make informed instructional decisions. Rehearsals serve as problem-solving spaces where teachers and facilitators can practice coordinating the complexities of classroom teaching, attending to the interactions between teacher, students, and the disciplinary content to be learned.[11]

Eight participants completed the survey, evaluating each session and rating its usefulness for their advising position. The nano bug activity was rated higher than the straw rockets challenge, but not as high as the student panel, pathways to engineering presentation, or the Diversity, Equity, and Inclusion in Engineering session. Table 1 shows the ratings of each session.

Table 1: Usefulness of information/activity for advising position



Self-Folding Challenges Results

Developing a PK-12 engineering challenge grounded in real-world research conducted by university faculty and students creates a meaningful connection between young learners and higher education. Rather than relying on a single individual's limited perspective to design a challenge, leveraging the breadth of research happening across a university allows for a diverse range of relevant, real-life issues to be explored. This approach enriches the learning experience for PK-12 students, highlights the real-world impact of engineering, and fosters a deeper, more authentic connection between the university and the community it serves.

It is important to design an engineering challenge that can be adapted—stretched or scaled down—to suit multiple age groups, as this approach increases the efficiency and sustainability of an outreach program. Using similar supplies and tools across different activities minimizes the need for a large inventory, making preparation and implementation more manageable. Additionally, creating tailored documents that reflect the developmental needs of various age groups helps staff recognize that learning occurs along a continuum and must be approached with age-appropriate strategies. Despite these differences, a single core concept can still be effectively explored and appreciated by students from early elementary through high school, reinforcing its relevance and accessibility across grade levels. An example of this is found in the

Activity Sheet for rising K-2nd vs rising 6th-8th grades in Figure 2: Rising K-2nd Grade Activity Sheet and Facilitator Notes and Figure 3: Rising 6th-8th Grade Activity Sheet, found in Appendix C and D.

The challenge of self-folding shapes from the summer engineering camp resulted in developing an engineering kit containing specialized materials and equipment for the academic year's short-duration engineering outreach programs. See Appendix B. We have already used it at several Partner Engineering Camps across North Carolina, during our on-site programs where we bring students to experience engineering at our campus, and at our Engineering on the Road programs, where we go to schools and provide engineering education activities. Unfortunately, the student evaluation data is no longer available.

Suggestions for Differentiating Engineering Challenges

The previous examples provide detailed examples of two engineering challenges differentiated for different grade levels, including a teacher professional learning session. While this paper focuses on informal educators, formal teachers could consider the strategies posed in this paper when differentiating activities for their grade level. When differentiating engineering activities for use with multiple-age levels or abilities, the following strategies may be helpful: 1) adjust the design complexity, 2) modify the constraints, 3) modify the criteria, and 4) add a cost and material constraint. The following provides examples of each recommended strategy:

Adjust the Complexity
Younger Grades
- Focus on single-step tasks or concepts (e.g., build a parachute that allows a payload to land safely).
- Use fewer or simpler materials (e.g., craft sticks, tape, pipe cleaners)
- Provide clear templates or examples.
- Incorporate guided instruction and step-by-step scaffolding.

Older Grades
- Introduce multi-step problems requiring iterative testing and improvement.
- Use a broader range of materials and allow more open-ended designs.
- Add complex goals (e.g., build a parachute that must achieve the longest descent time while protecting the payload)
- Encourage independent exploration and decision-making.

Modify the Constraints
Younger Grades
- Allow unlimited materials
- Provide premade components or partial designs

- Extend the time for building and testing
- Allow students to work in larger groups for collaborative problem-solving

Older Grades
- Limit the number or type of materials available.
- Add constraints, like limiting the size of the parachute or requiring it to fit into a launcher and deploy.
- Introduce external challenges (e.g., wind, rain)
- Shorten the time for design and iteration
- Partway through the working time, “recall” one of the materials

Modify the Criteria
Younger Grades
- Use binary criteria (e.g., did the payload land safely).
- Accept designs with minimal performance to build confidence.
- Offer simpler, more specific goals

Older Grades
- Introduce multiple performance criteria (e.g., the parachute must land in the target zone and stay afloat for at least 10 seconds).
- Evaluate efficiency
- Emphasize aesthetics, creativity, or sustainability.

Add a Cost and Material Constraint
Younger Grades
- Assign a set number of tokens or play money to purchase materials (e.g., straws = 1 token, tape = 2 tokens).
- Keep pricing simple and materials affordable to encourage creativity without frustration.
- Offer "free" materials to ensure all students can complete the challenge.

Older Grades
- Use more detailed pricing to simulate trade-offs (e.g., more substantial materials cost more).
- Introduce "bonus" costs for extras (e.g., extra time, additional testing).
- Incentivize using fewer materials or staying under budget (e.g., "Unused tokens = extra points).

Differentiating engineering challenges like the nanobug, self-folding shapes, and parachute examples above ensures that students across grade levels are engaged in meaningful, hands-on learning tailored to their skill level. Teachers and facilitators can foster critical thinking, creativity, and teamwork by gradually increasing the complexity, modifying constraints, and refining criteria. Introducing elements like budgeting and material constraints makes the challenges more realistic and highlights the importance of resource management and strategic planning in engineering. These adaptations allow students to experience the iterative design process, develop problem-solving skills, and gain a deeper appreciation for how engineers solve problems.

Limitations

One limitation of this work is the lack of student feedback data. As mentioned, many challenges occur in short-duration sessions of only 50-60 minutes. We have struggled to include an evaluation component, as it would reduce the already limited time for the activity.

Future Work

We are currently exploring how to evaluate these short-duration engineering challenges to receive student feedback for programming improvement. We are working with teachers to see if their students can complete the evaluation when they return to school the following day. We continue to develop hands-on engineering challenges and differentiate these activities for students across grade levels, helping us refine and expand our differentiation strategies.

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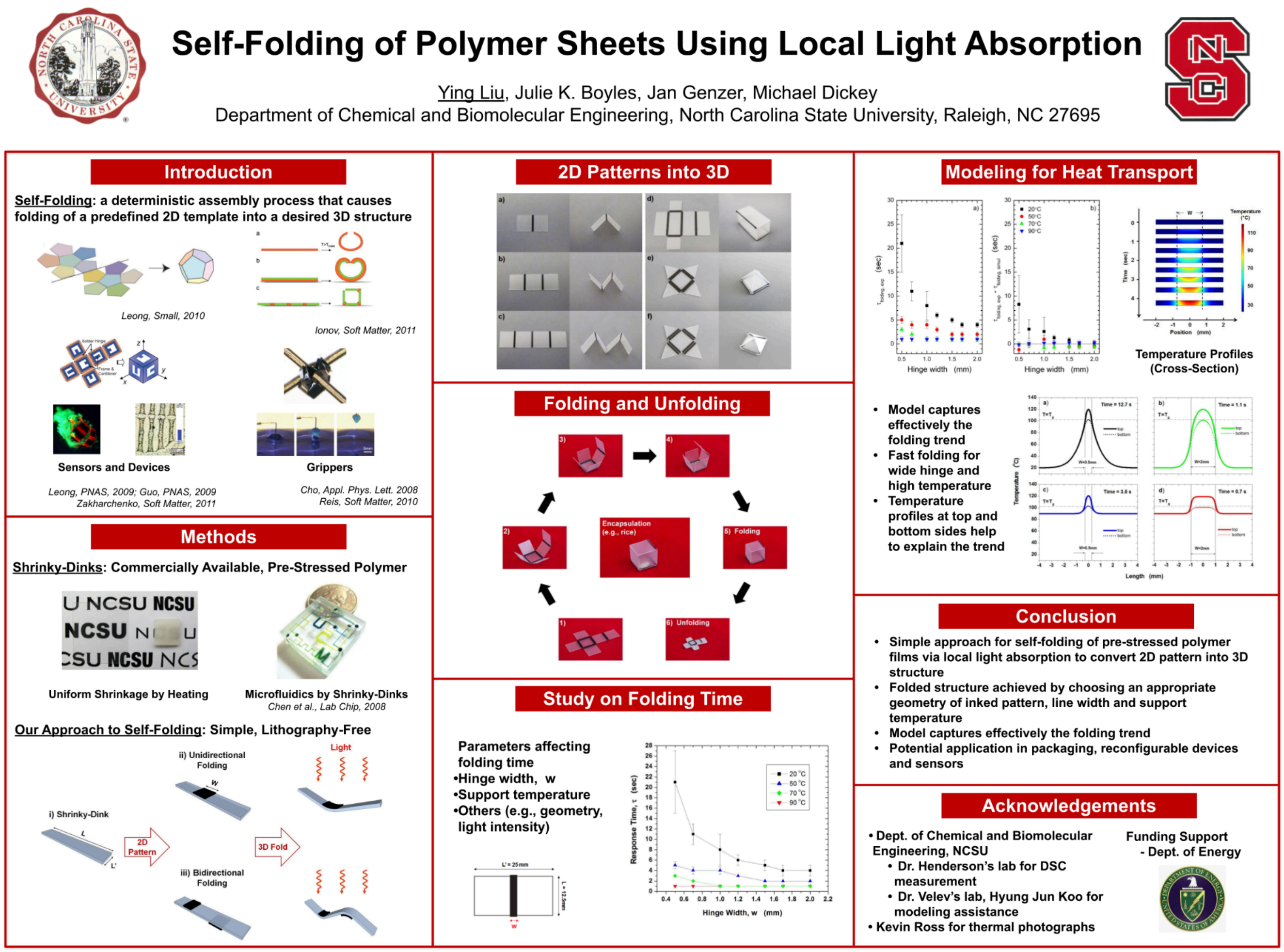
Appendixes

Appendix A

Diagram 1: Research Poster: Self-Folding Polymer Sheets Using Local Light Absorption



Appendix B

Figure 1: Self-Folding Shapes Kit Instruction Document

Self Folding Shapes Kit

the engineering place

Materials (Per Group):

1. China markers (3)
2. Pre-printed shrink film (9)
3. Blank shrink film (9)
4. Aluminum foil

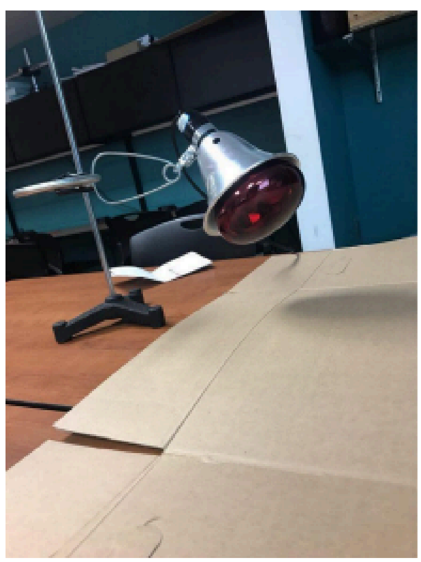
Tools: 3 rulers, 3 pairs of scissors, 3 pairs of sunglasses, 2 heat lamps, 2 titration stands, 2 cardboard sheets, 2 sets of tongs

Set-Up Protocol:

1. Clamp heat lamp to titration stand and place cardboard and aluminum foil directly below the lamp
2. Position lamp approximately 4 inches from the cardboard and aluminum foil.
3. Create a perimeter, using tape, on the ground around the table. The perimeter should be two feet from the edges of the table.
4. Each room should have two (do we have enough for 3?) titration stand-heat lamp apparatuses.
5. Be sure each lamp station has at least 3 pairs of sunglasses.

Activity Protocol:

1. Carefully cut out the pre-printed plastic outlines and place under the heat lamp.
    a. Repeat this for the other two pre-printed outlines
2. Using a China Marker, create your own 3D outline using the blank plastic shrink film
3. Cut out your outline and place under the heat lamp and observe the results
    a. Repeat this step for the other two blank sheets



Appendix C

Figure 2: Rising K - 2nd Grade Activity Sheet and Facilitator Notes

NC STATE

Exploratory: Self Folding Shapes

the engineering place

Design and create a 3-D shape using special plastic shrink film and heat.

Materials:
- China Markers (3)
- Pre Printed Shrink Film (9)
- Blank Shrink Film (9)

Tools:
- Rulers (3)
- Pairs of Scissors (3)
- Pairs of Sunglasses (3)
- Heat Lamp (2)
- Titration Stand (2)
- Cardboard Sheet (2)
- Aluminum Foil

Activity:
Wear your sunglasses
Set up heat lamp clamped to titration stand. Position heat lamp approximately 6 inches from the top of the hot plate (go closer if it takes too long)
Turn lamp on on
Cut out the pre printed shapes and place on hot plate directly under the heat lamp
Observe the shapes fold by themselves

Exploration:
Create and cut out your own 3D shapes using a China Marker or Black Sharpie
Place the cut out on the hot plate directly under the heat lamp
Observe results

Appendix D

Figure 3: Rising 6th - 8th Grade Activity Sheet

Self-Folding Shapes

the engineering place

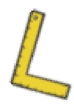
Objective: Create 3-D shapes using self-folding paper and heat.

Materials:

- Pre printed shapes on self-folding paper
- Blank self-folding paper
- China Markers

Tools:

- Scissors
- Heat lamp
- Titration Stand
- Rulers



Process:

2.Set up heat lamp clamped to titration stand. Position so heat lamp is approximately 8 inches from top of hot plate.
3.Turn hot plate on to 85°C.
4.Cut out pre printed shapes and place on hot plate directly under heat lamp.
5.Observe the shapes fold by themselves.
6.Create and cut out your own shapes, use the China Markers to draw folding lines.
7.Place on hot plate directly under heat lamp. Observe the results.

Requirements:

• Be very careful using the hot plate and heat lamp. If you touch them you WILL get burned.

•The self-folding paper can have sharp edges, use caution when cutting and handling.

ASK: What's the task?

- Create a folded shape using a pre-printed design, then create your own shape!

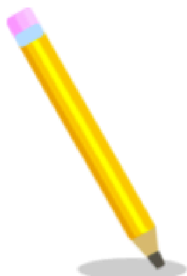
IMAGINE: List all of the ideas. Circle the best one.

- One line fold
- Book-shape (two lines close together)
- Zig-Zag (two lines equidistant on opposing sides of paper)
- M-shape (three lines equidistant with middle line on opposing side of paper)
- Three/Four sided pyramid
- Cube
- etc

PLAN: Draw a diagram of what you plan to create.

CREATE: How did your design work?

PLAN: Draw a diagram of what you plan to create.



IMPROVE: How can you make your design work better, use less material or take less time to create?

Should both sides of the paper be marked, or just one?
For what shapes would you need to draw on both sides of the paper?
For what shapes would you need to draw a thicker line?
Do thick lines fold faster or slower than thin lines?
Do large shapes fold faster or slower?