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The Design & Pitch Challenges in STEM: A Theoretical Framework for Centering Mathematics Learning in Entrepreneurial Pitch Competitions

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Abstract: Solving many of the pressing issues facing the world today will require a deep and integrated understanding of science, technology, engineering, and mathematics (STEM). To prepare today's K-12 students to tackle these challenges, STEM education must create opportunities to learn disciplinary content while inventing actionable solutions to messy, interdisciplinary problems. Learning frameworks, such as Project-Based Learning (PBL), Design-Based Learning (DBL), and Entrepreneurial-Based Learning (EBL), could support this reconceptualization of STEM education. New approaches are needed that leverage and integrate what works from these frameworks to better prepare students for success post-schooling. This means leveraging frameworks that emphasize practices and ways of thinking that support students to build and justify solutions that create value for users, while also creating a need for disciplinary content knowledge. This is especially necessary for mathematics, a discipline that is often treated insufficiently in interdisciplinary STEM activities. This paper introduces the Design & Pitch (D&P) Challenges in STEM Learning Framework, a novel learning framework that leverages features of PBL, DBL, and EBL, situating math learning within entrepreneurial pitch competitions. It describes the D&P Learning Framework and explores how each contributing learning framework combines to enhance students' work, focusing their mathematical reasoning, while also empowering them to invent relevant solutions to authentic problems.

Keywords: project-based learning; design-based learning; entrepreneurial-based learning; mathematics; STEM

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1. Introduction

Today's K-12 students will be confronted with unprecedented environmental, economic, and social challenges. Solving many of these significant and pressing issues will likely require a deep and integrated understanding of science, technology, engineering, and mathematics (STEM) combined with an entrepreneurial mindset that prioritizes innovation, actionability, empathy, and value creation (Organisation for Economic Co-operation & Development [OECD], 2018). To prepare students to take on these challenges, STEM education must create opportunities for students to engage with authentic interdisciplinary problems, while also learning specific disciplinary content (Organisation for Economic Co-operation & Development [OECD], 2018; Pearson, 2017). Novel curricular approaches are needed that allow students the autonomy to identify meaningful problems and pursue innovative solution paths, establish connections between in-school learning and their out-of-school experiences, and learn and apply targeted STEM content.

Curriculum theorists have developed learning frameworks that could support this reconceptualization of STEM education. These include, among others, Project-Based Learning (PBL) and Design-Based Learning (DBL), two learning frameworks that situate STEM learning within authentic contexts and challenges. More recently, researchers have begun exploring how Entrepreneurial-Based Learning (EBL; Pérez Yuste et al., 2014), a framework that uses authentic entrepreneurial processes to teach disciplinary content (Lackéus, 2015), can motivate learning and increase interest and engagement in STEM (Deveci & Seikkula-Leino, 2023; Newton et al., 2018; Yu et al., 2025). In isolation, each of these frameworks has shown promise for supporting interest, engagement, and learning in STEM (Cruz et al., 2022; Doppelt et al., 2008; Newton et al., 2018; Penner et al., 1998; Stevens, 2000; Wendell & Rogers, 2013). Synthesizing these frameworks within a single cohesive learning framework could enhance their potential for reconceptualizing STEM education, allowing researchers to leverage specific features from each.

The purpose of this paper is to introduce the Design & Pitch (D&P) Challenges in STEM Learning Framework (Confrey et al., 2019) that situates the learning and application of grade-level-specific mathematics content within week-long entrepreneurial pitch competitions. The framework was designed to allow for a variety of use cases, including as the primary activity that drives the learning of new mathematics content and skills or as a summative application of previously learned mathematics content. During the experience, teams of students invent their own entrepreneurial solutions to math-focused design challenges, define business plans, and deliver five-minute pitches to a panel of judges. We explain how the D&P Learning Framework combines elements of Project-Based Learning (PBL), Design-Based Learning (DBL), and Entrepreneurial-Based Learning (EBL) to enhance students' mathematical reasoning, while also empowering them to invent solutions to authentic problems that are both personally and socially relevant. We also provide details on the D&P Learning Framework and describe the nine curricular activities (challenges) we created to align to the framework. We conclude with a vision for how and why this novel curricular form can transform the teaching and learning of mathematics.

2. The Design & Pitch Challenges in STEM

The D&P Learning Framework uses authentic entrepreneurial processes to motivate the learning or application of curricular STEM content (Moberg, 2014), especially mathematics. More specifically, the D&P Learning Framework engages teams of students to collaboratively invent, prototype, and pitch innovative and actionable solutions to the real-world math-focused entrepreneurial design challenge detailed in a D&P curricular activity. The pitch, the culminating event for a challenge, is a short (maximum of five minutes) persuasive presentation in which teams attempt to convince a panel of external judges that their products or services are entrepreneurially viable. The following sections describe the novel integrated D&P Learning Framework and highlight how each component leverages specific features of Project-Based Learning (PBL), Design-Based Learning (DBL), and Entrepreneurial-Based Learning (EBL), the three learning frameworks that informed its design. This paper defines the Design & Pitch Challenges in STEM as a learning framework that drove the development of coherent curricular activities: tasks that can be used in classrooms to teach standards-aligned disciplinary content (Jukic Matić, 2019). To help illustrate the components of the D&P Learning Framework, we include descriptions of one challenge, Pollution Solution. Several student solutions, and their potential for supporting mathematical reasoning, are discussed to show how features of PBL, DBL, and EBL are leveraged to support interest, engagement, and targeted mathematical reasoning.

2.1. A Brief Overview of PBL, DBL, and EBL

The D&P Learning Framework integrates compatible features of Project-Based Learning (PBL), Design-Based Learning (DBL), and Entrepreneurial-Based Learning (EBL). The purpose of this integration was to build a novel learning framework that focuses and scaffolds students' innovative thinking and mathematical reasoning.

Project-Based Learning (PBL) uses authentic driving questions and relevant contexts to motivate the learning of curricular content (Barron et al., 1998; Capraro & Slough, 2013). Through sustained collaborative inquiry (Capraro & Slough, 2013; Schneider et al., 2002), students build artifacts and deliver culminating presentations that address an authentic driving question (Blumenfeld et al., 2006; J. S. Krajcik & Blumenfeld, 2006; Thomas, 2000). As students work, they continually reflect and iterate on their ideas, identifying gaps in their skills and working towards the disciplinary content goals of the project (Barron et al., 1998; J. Krajcik et al., 2007).

Design-Based Learning (DBL) engages students in design thinking as they iteratively build, test, and refine user-focused solutions to specific design challenges that, like PBL, are intended to create a need for the learning of disciplinary skills and content (English et al., 2020). As students progress through a challenge, they expose their prototypes to critique, which helps them to identify gaps in their understanding (relative to the content, context, and original designs) that need filling (Kolodner, 2002; Penner et al., 1998). DBL involves iteratively gathering and analyzing information (Fortus et al., 2004), generating possible solutions (Apedoe & Schunn, 2013), building, testing, presenting, and refining prototype solutions (Doppelt et al., 2008; Kolodner, 2002; Penner et al., 1998; Razzouk & Shute, 2012), and reflecting on their process (Fortus et al., 2004; Kolodner, 2002). At the end of a DBL challenge, students produce a final design artifact that meets the needs of intended users.

Lastly, Entrepreneurial-Based Learning (EBL) supports students to learn to think and act like an entrepreneur (Lackéus, 2015; Pérez Yuste et al., 2014). It can involve teaching students about entrepreneurial concepts or supporting them to learn entrepreneurial skills through engaging in authentic entrepreneurial processes (Lackéus, 2015; Moberg, 2014; Passaro et al., 2017). These include (a) "... defining situations, imagining scenarios and deciding what is to be done while minimizing risks" (Filion, 1994, p. 70); (b) collaborating, arguing, and debating ideas and processes with peers (Passaro et al., 2017); (c) reflecting on their knowledge and skills relative to a specific entrepreneurial opportunity; and (d) considering ways of providing value to customers (Lackéus, 2015). Although researchers and private companies have begun exploring ways of using entrepreneurship to motivate the learning of STEM content (Deveci & Seikkula-Leino, 2023; Yu et al., 2025) or to leverage DBL in entrepreneurial settings (Laptev & Shaytan, 2022), EBL does not require an explicit connection to the learning of such content.

While PBL, DBL, and EBL are similar in many ways, they also have distinct elements that serve to enhance learning environments. The D&P Learning Framework was designed to take these unique elements and build upon the overlapping foundation of the three frameworks to create a novel approach to mathematics learning. The following sections describe how the D&P Learning Framework leverages and integrates select features of PBL, DBL, and EBL to promote interest, engagement, and targeted mathematics learning.

2.2. Introducing the Competition

Each competition, prior to engaging with a specific challenge, begins with introducing entrepreneurship and elements of pitch competitions. The overarching pitch competition is designed to engage students in authentic entrepreneurial processes (e.g., idea generation, opportunity and resource analysis, building business models, iterating, problem solving,

building diverse teams, and pitching) and supports the development of entrepreneurial characteristics, such as resourcefulness, adaptability, and courage.

During the introduction of the competition, teachers facilitate a whole-class discussion in which students share their knowledge of entrepreneurship and pitch competitions and review the rules and specifications for the upcoming pitch competition. As part of this discussion, students explore the D&P Entrepreneurial Characteristics and Processes (see Figure 1), which focus their attention on several key characteristics (e.g., problem solving, resourcefulness, empathy) and processes (e.g., prototyping, iterating, market research) that promote an empathetic and action-oriented conception of entrepreneurship.

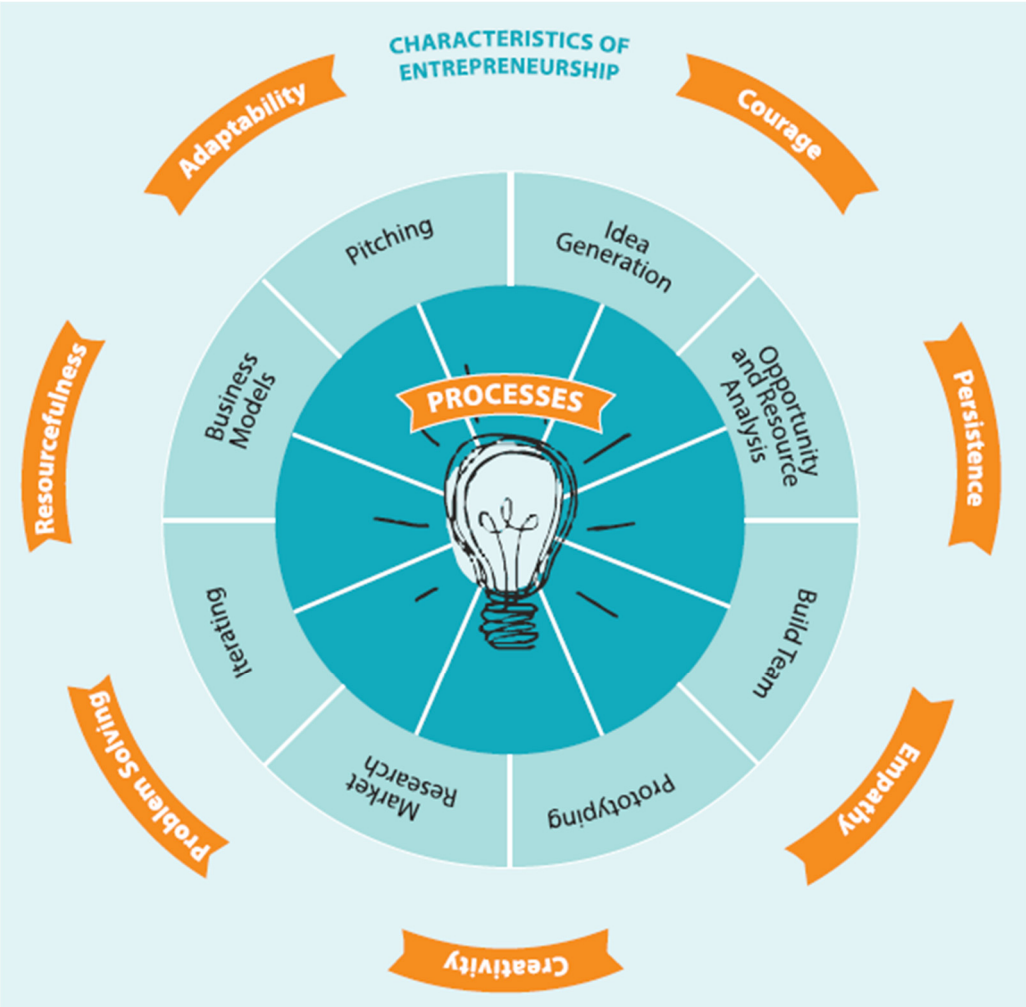


Figure 1. This is a figure of the D&P Entrepreneurial Characteristics and Processes developed by Confrey et al. (2019) in partnership with JASON Learning and informed by the work of Cristal Glanchai (2019).

The competition launch also includes watching a role model video in which a STEM or entrepreneurial professional discusses their experiences in entrepreneurship. The competition launch serves to orient students to the general goals of the activity (i.e., developing a solution to a challenging problem and pitching it to potential investors) and to get students excited about participating in a competition. It also helps focus students' attention on solving real problems in ways that are actionable and financially viable, as opposed to prioritizing profit for profit's sake.

Lastly, and most importantly for engagement and mathematics learning, the competition launch establishes a tangible and immediate purpose for students' work (Blumenfeld

et al., 2006; Condliffe et al., 2016; J. S. Krajcik & Blumenfeld, 2006). Students will work in teams to design a physical solution or artifact that addresses a given design challenge (Fortus et al., 2004; Wendell & Rogers, 2013), provide evidence of its potential entrepreneurial viability (Lackéus, 2015), and deliver a culminating presentation, in the form of a pitch, to investors (J. S. Krajcik & Blumenfeld, 2006; Passaro et al., 2017; Thomas, 2000).

2.3. The D&P Learning Framework

Creativity and innovation are defining characteristics of entrepreneurship (Bilen et al., 2005; Lackéus, 2015; Laptev & Shaytan, 2022). Although these characteristics can excite and inspire students, they also present an obstacle often confronted by mathematics educators: authentic entrepreneurial problems require innovative and unanticipated solutions, both in terms of the context of the solution and the mathematics used to design it. The D&P Learning Framework (see Figure 2) aims to overcome this obstacle by focusing students' entrepreneurial innovations through design challenges and criteria written to elicit specific mathematics content.

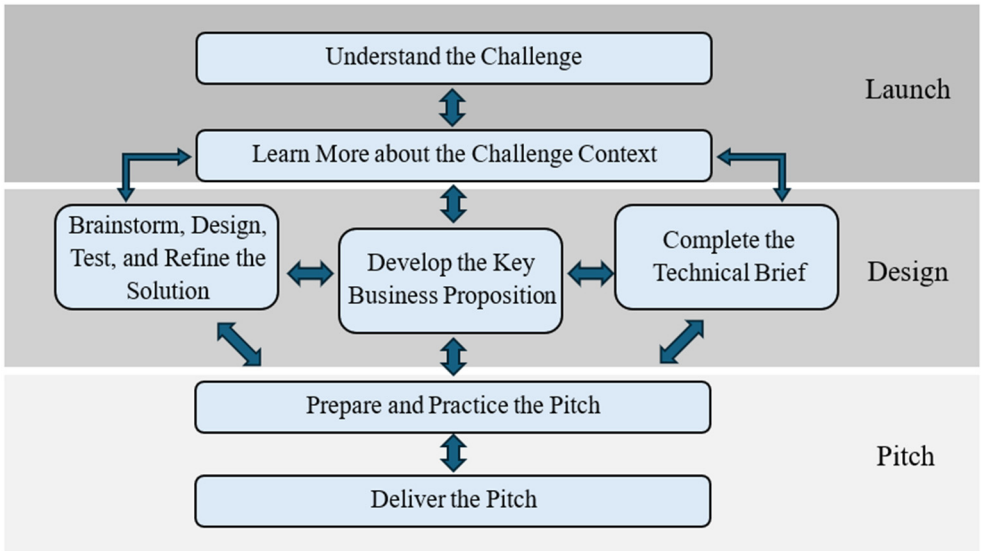


Figure 2. This figure shows the iterative design process that defines the D&P Learning Framework.

The D&P Learning Framework describes an iterative process through which students make sense of the challenge and context (Launch); brainstorm, prototype, refine, and describe entrepreneurial solutions to those challenges (Design); and pitch their solutions to a panel of external judges (Pitch). An in-depth exploration of how students' mathematical reasoning relative to a specific mathematics topic has been reported on in other publications (see e.g., Belcher et al., 2021, 2024). This paper willdescribe the phases of the process, using the Pollution Solution challenge to highlight how each phase draws on features of PBL, DBL, and EBL.

Following the description of the D&P Learning Framework, an overview of the complete set of aligned middle grades challenges will be provided. It is important to note that, although the framework and this paper are organized around the student process, teachers play an essential role in facilitating a challenge. Teachers are encouraged to frequently check in with teams, probe student thinking, reinforce challenge criteria, and provide targeted math support, in the form of individualized support or small group workshops, when needed. Key teacher moves will be discussed as they arise within the D&P Learning Framework sections.

2.3.1. Launch

After introducing the competition and orienting students to the characteristics and processes of entrepreneurship, teachers launch the specific math-focused entrepreneurial design challenge with students. The D&P Learning Framework engages students in addressing authentic driving questions through designing entrepreneurial solutions to math-focused design challenges. For example, in Pollution Solution (see Figure 3), students are tasked with addressing the broad driving question of how to decrease plastic pollution through the challenge of designing a non-plastic container for a liquid product.

Your challenge is to **propose a business around producing and selling a liquid consumer product that is packaged in a dissolvable or edible non-plastic container**. Your business should include:

1. A description of the liquid consumer product your business will sell and its purpose.
2. A 3D sketch and justification of the most appropriate shape and size for your product, given its purpose.
3. A detailed plan, with a 3D sketch and justification, for how you will package and ship your product.

Figure 3. This figure shows the challenge statement for Pollution Solution.

The challenge focuses students' project work and innovation, which places boundaries on the mathematics students are likely to use, while also allowing them the autonomy to identify both the liquid product and the material they use to package it. The challenge launch supports students to understand the challenge, learn more about the broader context in which the challenge is situated, reflect on their experiences with the context and challenge, and begin to empathize with their intended users and define what they need in a solution.

Understand the Challenge

Drawing from PBL and DBL, the D&P Learning Framework follows the introduction of the competition with a challenge launch in which students work collaboratively to understand the challenge and learn more about the challenge context. Students often have experiences with the challenge, context, or existing products that relate to the challenge and context. The challenge launch leverages these experiences to generate excitement through a brief whole-class discussion in which students reflect on and share their experiences with the challenge context. This discussion encourages students to connect their out-of-school experiences with the design challenge and positions them as both designers and clients/consumers of the product or service. Additionally, this initial launch centers the authenticity of the challenge and allows it to drive students' mathematical decision-making as they build their solutions. For example, in the Pollution Solution challenge, students reflect on their usage of single-use plastics, reasons that make single-use plastic ubiquitous, the environmental impact of single-use plastics, and existing solutions with which they are familiar. Through these reflections and conversations, students are primed to connect with and understand the scope of the problem, begin to consider and internalize the needs of their target consumers, and define the criteria that would make their proposed solution viable.

Following the whole-class discussion, students are shown a challenge champion video and the challenge statement. Each challenge in the D&P Learning Framework includes a challenge champion video. In the challenge champion video, a STEM or entrepreneurial professional whose work is related to the challenge context introduces the challenge and describes the general criteria for a solution. In the Pollution Solution challenge, the challenge

of designing a liquid product contained in a plastic alternative is introduced by Clifford Okoth Owino. The chief executive officer (CEO) of Chemolex, Okoth Owino, invented a way to turn a harmful invasive plant into an alternative to plastic. In doing so, he found a way to help his community by removing (and repurposing) an invasive plant, while also inventing an eco-friendly replacement for single-use plastics.

Students then read the challenge statement, which adds detail to the challenge champion video and includes: (a) a summary of the challenge, (b) a detailed description of the context in which the design challenge is situated, (c) a statement of the specific design challenge, and (d) a description of the criteria against which final designs will be evaluated. In the Pollution Solution challenge, the criteria specify that student solutions must include: a description of the liquid consumer product their business will sell and its purpose; a three dimensional (3-D) sketch and justification of the most appropriate shape and size for their product given its purpose; and a detailed plan, with a 3-D sketch and justification, for how the product will be packaged and shipped that includes the size, shape, surface area, and volume of the product container.

The challenge launch is intended to engage students in entrepreneurial processes, highlight entrepreneurial characteristics (e.g., empathy, creativity, idea generation, opportunity, and resource analysis), and establish a concrete foundation that will drive students' mathematics learning. The launch of the design challenge may also "trigger" certain student ideas or actions (Fortus et al., 2004), giving them an entry into the challenge. Although these activities are started in the challenge launch, it is an iterative process, with students developing a deeper understanding of both the challenge and the context as they build, test, and refine their solutions.

In both PBL and DBL, the launch is essential to students' understanding of the project or challenge. In PBL, it provides students the opportunity to collectively focus the task Tand identify the content and skills needed to complete it (Barron et al., 1998; J. S. Krajcik & Blumenfeld, 2006; J. Krajcik et al., 2007), thereby creating a need for new learning. In DBL, it engages students (individually, in groups, or as a class) in a process of "problem scoping" or "problem formulating" in which they begin "clarifying and restating the goal of the problem, identifying constraints to be met in problem solution, exploring feasibility issues, drawing on related context to add meaning, experimenting with materials, and establishing collaborative group work" (English & King, 2015, p. 4). This problem-scoping stage focuses students' attention on the specific criteria that will determine the success of a design (Kolodner, 2002; Fortus et al., 2004; Penner et al., 1998; English & King, 2015). It helps orient the class, supports students to attend to the relationship between the problem and any proposed solutions (Penner et al., 1998), and can initiate student action through their familiarity with the context (Fortus et al., 2004).

Learn More about the Challenge Context

Once students have a fundamental understanding of the challenge, they begin learning more about the challenge context as they collaboratively research the overarching driving question and the ways entrepreneurs and scientists are currently addressing it. This initial step of research engages students in entrepreneurial processes such as empathy and opportunity and resource analysis, and encourages them to think big, attending to the viability and authenticity of a solution.

The research phase includes two additional resources designed to support students to learn more about the challenge context. The first is the Helpful Resources document, a set of internet hyperlinks to news stories about the context or to websites of companies doing work relating to the challenge context. Understanding the needs of users, often through market research, is essential to entrepreneurship. The Helpful Resources document is an effort to translate this entrepreneurial experience to the classroom. Through the set of links,

the resource provides students with additional information about the context, users, and existing entrepreneurial solutions to help them gain insight into how others have solved the problem and what users may want in a solution. These links were curated and designed to jumpstart student thinking and highlight the authenticity of their work. In Pollution Solution, the set of resources explores the extent and environmental implications of the single-use plastics problem and lists innovative alternatives that are either currently in use or being developed. The research phase and the Helpful Resources not only provide deeper insight into the importance and urgency of the broader context of the driving question, but also help students connect, on a personal level, with the challenge.

The second resource is a background video in which the challenge champion gives students more information about their careers and provides tips for students to consider when building their solutions. Integrating the Helpful Resources and Background Video within the research process is intended to further support students to attend to constraints authentic to the challenge context and the needs of their intended users. Additionally, it positions them as both the designer and user of the solution, which gives them a frame of reference for evaluating the completeness and success of their solutions. For Pollution Solution, the challenge champion discusses in greater depth the origin of his innovative bioplastic, how it connects to his life experiences as the son of a fisher, and how his company considered the unique needs and desires of his community: the people he most wanted to help with his solution. Okoth Owino's decision to use an invasive plant as the primary material for his bioplastic emerged from his experiences witnessing the damage the plant was doing to his father's livelihood. Okoth Owino was uniquely positioned, through the combination of his life experiences and STEM training, to capitalize on this entrepreneurial opportunity. In this way, the background video not only gives students insight into the importance of understanding one's community and empathizing with the needs of their users, but also empowers them to draw on their experiences and STEM knowledge in inventing entrepreneurial solutions. This was evident in a solution from one team of middle school students. Like Okoth Owino, they identified a locally invasive plant with which they were familiar (bamboo) and designed a cylindrical water bottle made from sections of that plant. In this way, the background video may have jump-started students' idea generation, leading them to a solution that was authentic, personally relevant, and that would provide the focus of their engagement with the intended mathematics content.

2.3.2. Design

Following the challenge launch, students start working through three parallel and iterative components of the D&P Learning Framework: (a) brainstorm, design, test, and refine solutions; (b) develop the Key Business Proposition; and (c) build the Technical Brief. The work of designing a prototype solution, defining its entrepreneurial viability through a business proposition, and documenting its mathematical foundation happens within this Design phase. Although these three phases are depicted in the D&P Learning Framework as distinct, they are nevertheless highly interactive and iterative, with each phase informing the other two and students frequently cycling between the three.

Brainstorm, Design, Test, and Refine Solutions

The brainstorming phase of the solution design process establishes an essential foundation that will drive students' mathematical and entrepreneurial reasoning throughout the competition. It is during this phase that students collaboratively draw on their personal out-of-school experiences, interests, and expertise to identify entrepreneurial opportunities and begin defining solutions that capitalize on those opportunities. This accomplishes several beneficial outcomes for students' mathematics learning. First, it engages students more broadly in authentic mathematics problem solving. Rather than providing students

with a pre-selected or pre-configured "real-world" problem, students are empowered to identify, within the challenge context, their own problem to solve and define the relevant parameters. Second, it connects students' in-school learning to their out-of-school experiences, demonstrating the utility of mathematics learning beyond the classroom. Finally, it positions students as experts, relative to their chosen solution path, empowering them to self-evaluate the correctness or completeness of their solutions and the underlying mathematics. Take for example, the team of students who addressed the Pollution Solution challenge by inventing a water bottle made from a cylindrical bamboo stalk. Although one could argue this solution does not meet the challenge requirement that the container be made from "dissolvable or edible non-plastic material," the bamboo water bottle would nevertheless allow students to address the math-focused criteria and, thus, engage with the intended mathematics content. To be able to determine the amount of water their bottle could hold, students would need to make assumptions about how to model a bamboo stalk (bamboo stalks are not uniformly cylindrical and have thick outer walls), define the dimensions of a section of the stalk, and consider the relationship between those dimensions and the amount of water the stalk could hold. Other solutions included beeswax cubes that would hold honey and spherical edible pods containing water. Each of these liquid products introduces unique and authentic constraints for students to consider in quantifying the volume and surface area of the containers.

Once students have arrived at a general idea for a solution, they begin designing, testing, and refining it, often using D&P-identified technological tools. In each challenge, the D&P Learning Framework includes technological tools, specifically identified to support students in prototyping their solutions and engaging with the targeted mathematics content. In Pollution Solution, students use the free online 3-D design software TinkerCAD (Autodesk, 2025) to create 3-D models of their containers. TinkerCAD allows students to design and manipulate 3-D figures, supporting the development of students' spatial reasoning and highlighting the relationship between the dimensions/shape of a figure and its apparent capacity.

The process of brainstorming, designing, testing, and refining their prototypes to meet the design criteria is intended to help students identify gaps in their math content knowledge or skills and work to fill those gaps by seeking out additional resources (Capraro & Slough, 2013; Kolodner, 2002; J. Krajcik et al., 2007; Penner et al., 1998), including teacher support and a math resource tailored to each challenge. It also leverages students' design preferences and real-world experiences as consumers to motivate and inform valuable mathematical considerations. For example, in the Pollution Solution challenge, students need to coordinate between the design of their liquid container, its volume and surface area, and the needs of users. This coordination requires students to draw on their experiences as users of the product, their aesthetic preferences for the appearance and form of the container, the financial incentive of minimizing the container's surface area, and the industry expectations for the container's volume. For example, users' expectations for the volume of a water bottle are likely different from their expectations for the volume of a honey cube or an edible water pod, and students must consider those expectations in designing their containers.

The theory informing the brainstorm, design, test, and refine component of the D&P Learning Framework leverages features of EBL, PBL, and DBL. In PBL, students work collaboratively in "communities of learners... including peers, teachers, and members of the community" (Schneider et al., 2002, p. 3) to address the driving question through the creation of a tangible artifact, which can include physical products, sketches, plans, or even posters (Blumenfeld et al., 2006; Capraro & Slough, 2013; Condliffe et al., 2016; Cruz et al., 2022; Fisher et al., 2020; Thomas, 2000). The creation of the final product provides a

concrete outcome for students' schoolwork (Blumenfeld et al., 2006), which can create an immediate purpose for learning that motivates student engagement (Ainley et al., 2005; T. J. Moore et al., 2020). DBL uses design thinking to provide a structure for students' collaborative work (Dym et al., 2005; Kolodner, 2002) and includes opportunities to more explicitly connect that work to specific mathematics learning goals (Apedoe & Schunn, 2013; Mehalik et al., 2008; Penner et al., 1998). After launching the design challenge and establishing initial conditions and criteria against which designs will be evaluated, students engage in an iterative process of gathering and analyzing information (Fortus et al., 2004), generating possible solutions (Apedoe & Schunn, 2013), building, testing, presenting, and refining prototypes (Doppelt et al., 2008; Kolodner, 2002; Penner et al., 1998; Razzouk & Shute, 2012), and reflecting on their process (Fortus et al., 2004; Kolodner, 2002).

Develop the Key Business Proposition

For an entrepreneurial solution to succeed, it must create value for consumers or customers (Jones et al., 2020; Lackéus, 2015). That is, it must solve a problem, fixing something a user dislikes or enhancing something they like about their situation. If an entrepreneur cannot communicate a convincing value proposition to investors, consumers, and customers, the product or service is unlikely to succeed. As students brainstorm, design, test, and refine their solutions, they are also supported to define their solutions' value propositions using the Key Business Proposition (KBP). The KBP includes three parts. The first part of the KBP is shown in Figure 4.

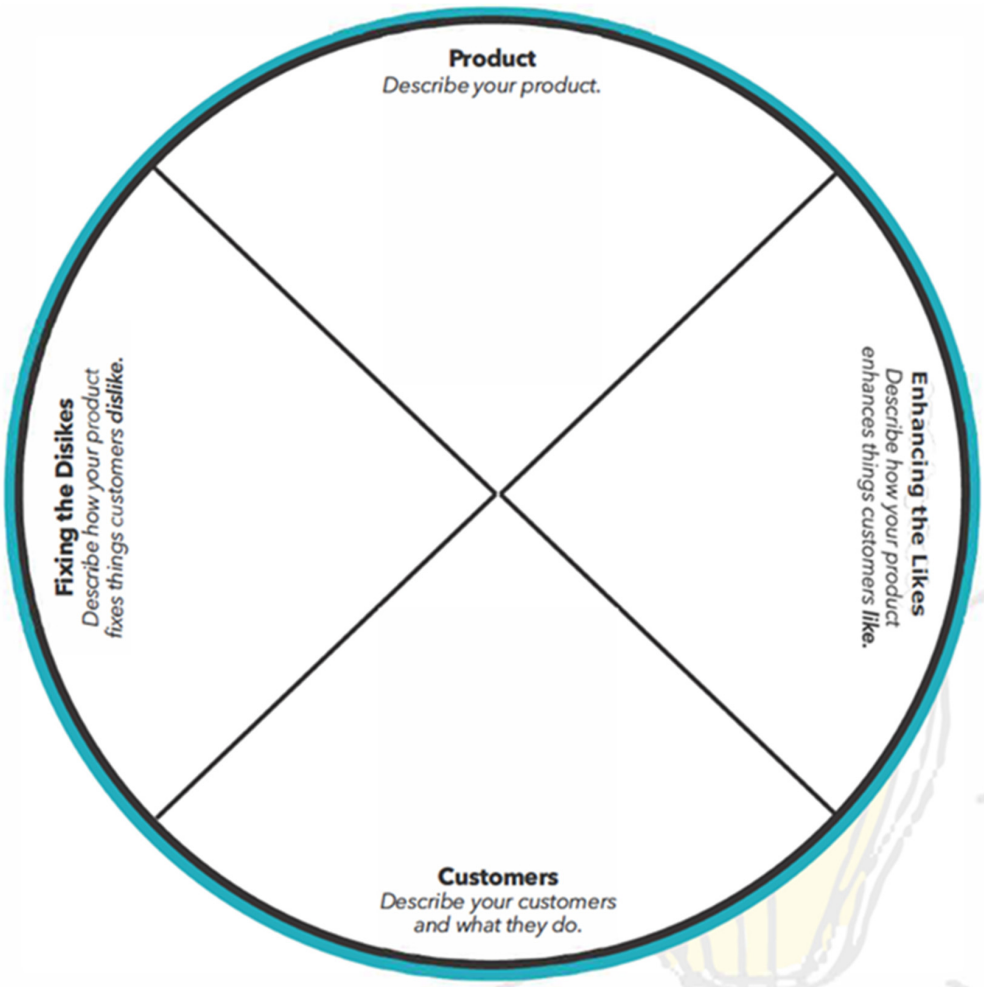


Figure 4. This figure represents the first part of the Key Business Proposition.

It provides a structure for students to describe the features of their product, identify their target customers, and define how their product will fix something customers dislike about their situation or enhance something they like about their situation. For example, in Pollution Solution, students need to coordinate between enhancing features that consumers like about bottles (e.g., ease of use, lightweight and durable materials, portability, aesthetics) and fixing features they dislike about plastic bottles (e.g., plastic pollution, release of harmful chemicals over time, use of a non-renewable resource). These considerations inform students' design decisions, which then often introduce mathematical constraints on their solutions, such as guaranteeing that the resulting container is lightweight, made from eco-friendly materials, and holds an amount of liquid that fits users' expectations. This requires students to coordinate between the volume and surface area of the container as they make adjustments to meet users' expectations. For example, students would need to consider the relationship between the dimensions of a section of bamboo stalk and the amount of water it can contain. Similarly, meeting user expectations for the amount of honey in an edible honey cube or water in an edible water pod requires students to coordinate between the dimensions of the container and its volume.

The second part of the KBP prompts students to identify a type of business model they will use to make their solutions financially viable. The D&P Learning Framework includes a Business Model Types resource that describes several common business model types. It is intended to introduce students to different types of business models while also focusing their attention on the actionability of their solutions. The final part of the KBP is an Elevator Pitch template (see Figure 5).

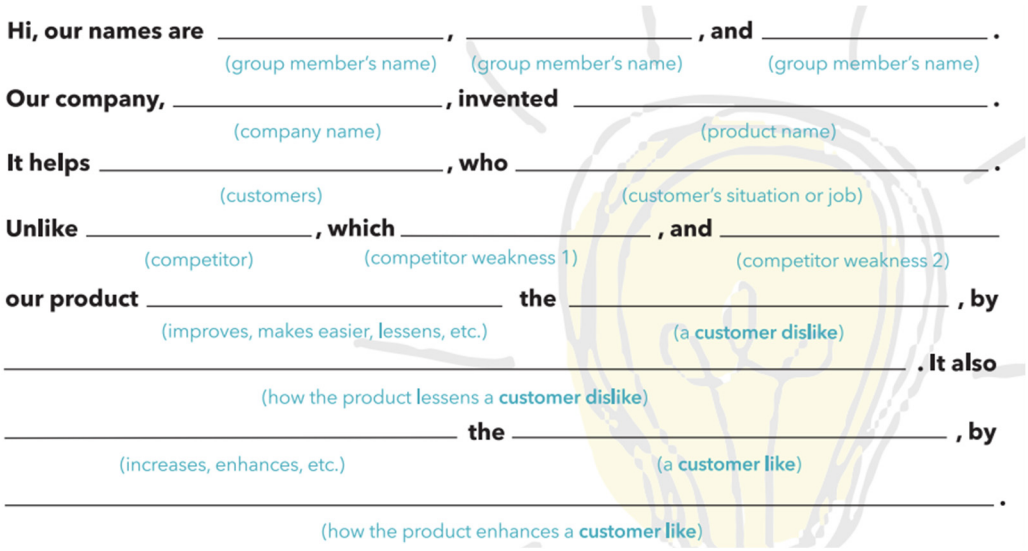


Figure 5. This figure shows the Elevator Pitch Template included in the Key Business Proposition.

The Elevator Pitch template provides students with a structured way to begin planning how to effectively and concisely communicate the features of their solution, describe its value proposition, and position it in the market relative to competitors. Focusing students' attention on their consumers and competitors, the elevator pitch not only creates opportunities for students to continue practicing communicating and defending their reasoning, but it also introduces additional considerations that can lead students to self-evaluate and iterate on their designs. As students reflect on how their solutions compare to their competitors, they often discover ways in which those solutions fall short of their competitors and are, thus, in need of improvement.

PBL and DBL both emphasize authenticity, through engaging in career-connected processes (Grossman et al., 2019; J. S. Krajcik & Blumenfeld, 2006; Thomas, 2000), addressing

real-world driving questions (Capraro & Slough, 2013; Grossman et al., 2019; Schneider et al., 2002), and designing tangible artifacts or prototypes (Blumenfeld et al., 2006; Capraro & Slough, 2013; Condliffe et al., 2016; Cruz et al., 2022; Fortus et al., 2004; Mehalik et al., 2008; Wendell & Rogers, 2013). The KBP draws on EBL to enhance the authenticity of projects and design challenges, by focusing students' attention on the entrepreneurial viability of their solutions. That is, to be authentically actionable, students' solutions must create value for a specific group of customers or consumers (Borasi & Finnigan, 2010; Jones et al., 2020; Lackéus, 2015). In both DBL and EBL, students play a central role in defining the criteria for a successful solution and making necessary adjustments to those criteria based on value judgments (Apedoe & Schunn, 2013; Dym et al., 2005; Kolodner, 2002). Where EBL differs from DBL is in its emphasis on not just the needs of the customer, but on identifying and communicating the value proposition of a design (Lackéus, 2015). Through the KBP, the D&P Learning Framework provides students with a way of defining the criteria for a complete solution that takes into consideration the needs of the target user/consumer and the actionability of the solution.

The KBP supports learning and promotes entrepreneurial characteristics and processes in several ways. First, it encourages empathy, as students consider the needs of customers. Second, it promotes problem solving, as students consider how to adapt or better position their ideas to create value for customers. Third, it supports learning by leveraging the evaluation and critique component of DBL. In DBL, it is important for students to consider alternative designs, to make value judgments relative to the criteria for success, and to select the optimal or preferred design for the final product (Dym et al., 2005). Finally, the KBP utilizes an elevator pitch framework (see Figure 4) to help students begin considering how to concisely describe their business and product, while positioning it in the market relative to competitors.

Build the Technical Brief

The third component of the Design phase of the D&P Learning framework is completing the Technical Brief. In completing the Technical Brief, students describe the specifics of their solutions, including mathematical and scientific justifications, and discuss the process through which they developed their solutions. The goal of the Technical Brief is to encourage students to demonstrate how they know a solution will work and that it meets the specific challenge criteria, using the targeted mathematics content. It includes two parts. In the first part of the Technical Brief, students reflect on their process of designing, testing, and refining their solution, including describing the research they conducted and the solutions they considered but chose not to pursue. In the second part of the Technical Brief, students describe the specifics of their solution and how it addresses the challenge criteria, which involves explicitly showing their mathematical reasoning.

In the Pollution Solution challenge, the Technical Brief makes explicit the requirement for students to create 3-D models and calculate the volume and surface area of their liquid container. Students are also prompted to describe how they arrived at their final designs and justify the entrepreneurial and scientific viability of their designs. These requirements connect students' entrepreneurial designs to the intended mathematical content relating to the measurement of 3-D figures. The D&P Learning Framework also includes a Technical Brief Rubric aligned to the Technical Brief that makes students aware of the expectations of what to include in the Technical Brief and guides teachers in their assessment of students' understanding of the intended mathematics content.

In both PBL and DBL, reflecting on the process of developing the final artifact is essential for connecting the design or project tasks with the underlying STEM content and skills (Kolodner, 2002; J. Krajcik et al., 2007; Penner et al., 1998). In PBL, this reflection may occur through scaffolded lessons implemented during the unit (J. Krajcik et al., 2007) or

through project journals in which students document their process and the problems they choose to solve (Stevens, 2000). In DBL, reflection might involve whole-class presentations (Fortus et al., 2004; Penner et al., 1998), gallery walks, design journals, guided inquiry lessons during the design process (Kolodner, 2002), or through testing and reflecting on the success of prototypes (Doppelt et al., 2008; Kolodner, 2002; Penner et al., 1998; Razzouk & Shute, 2012). The Technical Brief provides a structure for supporting this reflection, while also encouraging students to show how their solution meets the specific design criteria, using the intended mathematics content.

Exposing Ideas to Critique

As students design their solutions, define value propositions through the KBP, and describe the entrepreneurial and mathematical specifications of their solutions through the Technical Brief, the D&P Learning Framework incorporates frequent opportunities for students to practice sharing their thinking, expose their ideas to critique, and receive feedback from teachers and external audiences. Throughout the competition, teachers are encouraged to conduct informal check-ins, asking students to explain their solutions, describe how those solutions address specific challenge criteria, identify their target customers, and justify how their solutions create value for those customers. These informal check-ins leverage the authenticity and entrepreneurial viability of student solutions to prompt students to reflect on the targeted mathematics. For example, in the Pollution Solution challenge, teachers frequently ask questions like, "What type of liquid product will your container hold? How much liquid will it hold? How did you decide on that amount? Who are your target customers? And what aspects of your product will make customers want to use it?" These questions prompt students to reflect on the relationship between the design of their container, its volume and surface area, and the expectations and needs of the customers. In this way, the authenticity of the situation leads students to evaluate the accuracy of their prototypes and calculations and iterate as needed.

The D&P Learning Framework includes a more formal opportunity for students to expose their solutions to critique through the Expert Check-In, in which students describe their solutions to a member of the community who has not engaged with the students about their solutions previously. During the Expert Check-In, the expert, like the teacher, is encouraged to follow student thinking, asking questions about the real-world and entrepreneurial viability of solutions to drive back at the math-focused challenge criteria. The Expert Check-In provides students with another opportunity to test the viability of their solutions, this time with a new audience, and to practice explaining and defending their design decisions. Together, the teacher, through their frequent informal check-ins, and the experts, through their more formal check-ins halfway through the competition, press students to explain and defend features of their solution and value proposition. These check-ins (a) provide students with helpful guidance for improving their solutions; (b) create opportunities for students to practice explaining and defending their solutions; (c) help students identify gaps in their solutions that to fill require engagement with the intended mathematics content; and (d) build students' investment and confidence in their solutions.

Peer feedback is central to PBL, driving students to iterate and improve on their tangible artifacts and final presentations, while also creating opportunities to identify gaps in their discipline-specific knowledge or skills (Condliffe et al., 2016; J. S. Krajcik & Blumenfeld, 2006; Schneider et al., 2002; Thomas, 2000). The D&P Learning Framework draws on the feedback structures characteristic of DBL and EBL to focus and enhance this component of PBL. In DBL, students are given frequent opportunities to expose their prototypes to critique, often through testing their designs under real-world circumstances. This could include things like testing a parachute design by dropping it from some height (Kolodner, 2002) or testing a physical model of an elbow to evaluate whether it behaves

as expected (Penner et al., 1998). The purpose of exposing the prototype to critique is to allow real-world constraints to determine the success or failure of a design. When a design fails (or does not behave as expected), students must reflect on their prototypes, identify and work to fill gaps in their understanding that led to the design failure, and refine their designs using the newly learned knowledge or skills (Skinner & Harlow, 2022). Entrepreneurs similarly build, test, and refine prototypes of their products. They also frequently seek out feedback from peers, experts, and their intended users and utilize that feedback to improve their designs.

2.3.3. Pitch

The final component of the D&P Learning Framework is pitching and includes both a practice pitch with an external judge and the final pitch competition with a panel of judges. The final pitch in the D&P Learning Framework is restricted to five minutes, without question, which requires students to clearly, concisely, and thoroughly communicate the features of their solution and convince the judges of its viability. This final pitch situates and reframes the presentation components of both PBL and DBL within an authentic, exciting, and high-pressure entrepreneurial experience of the start-up competition (Bilen et al., 2005; R. A. Moore et al., 2017; Passaro et al., 2017).

Prepare and Practice the Pitch

To help students learn to build a pitch deck and plan their entrepreneurial pitch, the D&P Learning Framework provides a set of pitch resources. These resources include a How to Build a Pitch document, which outlines the key components of an effective pitch, a set of sample pitches from real companies, which helps students understand what a pitch looks like and important elements to include, and a pitch judging rubric that will be used by the judges to evaluate each of the solutions and choose a winning team.

One to two days before the final pitch competition, students are given an opportunity to complete a practice pitch to an external practice judge. External practice judges can be anyone who is not the students' teacher because the teacher already has a deep understanding of each solution. Not only is the practice pitch an opportunity for students to have a trial run at their pitch, but this provides time for the students to receive critical feedback so they can develop their ideas and how they communicate those ideas more completely before the final pitch. The practice pitch is intended to give students one more opportunity to expose their ideas to critique and make necessary improvements before the final pitch, while also continuing to build their confidence in their solutions and their excitement to share those solutions with the judges and their peers.

The importance of preparing and practicing the pitch goes beyond improving the solution and final pitch. The act of communicating one's thinking thoroughly, convincingly, and concisely to an unfamiliar audience is a challenging and intimidating prospect that requires considerable courage. It increases student accountability and inspires action. Typically, halfway through the competition, students start to feel the pressure of the practice pitch, and their intensity and collaboration inevitably increase. They start to assign roles for the pitch, identify the key elements they need to communicate in their pitch, and plan how to do so effectively through visuals, text in their pitch decks, and a verbal script. After delivering their practice pitches, they come to understand the daunting nature of the task, often realizing just how short five minutes feels when they are excited to share their ideas with the judges, and how much practice they need to be able to comfortably explain and pitch their innovations. This often leads teams to repeatedly and iteratively plan, discuss, write, practice, and reflect on what and how they are communicating to the judges, including both the purely entrepreneurial aspects of their solutions and the underlying mathematics.

Deliver the Pitch

Each D&P challenge culminates with a five-minute pitch to a panel of judges. Depending on the setting and the resources available, the panel of judges could be members of the community, local entrepreneurs, or school stakeholders. The only requirement for judges is that they are not familiar with students' entrepreneurial solutions prior to the final pitch. By the time students make it through the week of designing their solutions, defining their business value propositions, defending their thinking to teachers and outside experts, and preparing and practicing their pitches, students are often nervous and excited to show off what they have accomplished. On the day of the final pitch competition, students continue running through their pitches (often pacing back and forth with notecards) and tinkering with their slide decks (typically a Google Slides or PowerPoint presentation), which provides additional opportunities for students to practice communicating and reflecting on their solutions and the underlying mathematics. The autonomy afforded by the entrepreneurial pitch format adds to the appeal and excitement of a final presentation. While daunting and requiring courage, it allows students the opportunity to share something unique and personally relevant with outside experts. Students get excited to share what they have learned with adults who want to listen to what they have been working on. Upon completing their final pitches, students often report feeling proud of their work and identify ways they could have improved.

Preparing for and delivering the final pitch has roots in all three instructional frameworks that informed the design of the D&P Learning Framework. In PBL, projects culminate with a final presentation in which students share their work with an external audience. The final presentation provides added accountability to students' work and an opportunity to reflect on the connections between the project work and the targeted disciplinary content (Condliffe et al., 2016; Grossman et al., 2019; J. S. Krajcik & Blumenfeld, 2006; J. Krajcik et al., 2007; Thomas, 2000). Similarly, in DBL, the expectation that students continually expose their ideas to critique is intended to allow students to evaluate their prototypes and connect the features of their designs to the intended STEM content (Kolodner, 2002; Penner et al., 1998). EBL adds a unique twist to these public presentations, making them persuasive and investor-focused. In EBL, the final presentation of a solution, product, or service often takes the form of a persuasive pitch to investors (Bilen et al., 2005; Passaro et al., 2017). Like PBL and DBL, the pitch, delivered to an external audience, requires students to develop and deliver a clear, concise, and convincing explanation of their solutions.

2.3.4. Summary

The D&P Learning Framework leverages and enhances compatible features of PBL, DBL, and EBL to create an integrated learning framework that can support targeted mathematics learning. Table 1 shows how PBL, DBL, and EBL informed the D&P Learning Framework. It should be noted that PBL, DBL, and EBL all share similar features, and most of the D&P Learning Framework components were informed by more than one framework. For example, PBL and DBL both include opportunities for students to expose their ideas to critique through a final presentation or testing of a prototype. The D&P Learning Framework leverages the entrepreneurial pitch competition (an authentic entrepreneurial process) to heighten the excitement, accountability, and autonomy of this public presentation. Likewise, while PBL emphasizes autonomy and EBL emphasizes innovation and uniqueness in the development of artifacts and products, DBL's emphasis on design challenges and user-focused design criteria was leveraged to focus students' innovations and provide predictability in the math that will emerge as students build those innovations. Lastly, while both DBL and EBL are intended to motivate the learning of disciplinary STEM content, PBL

provides a structure, through workshops and content rubrics, for supporting students to draw connections between their project work and the intended STEM learning goals.

Table 1. The D&P Learning Framework Components Summary.

D&P Components	PBL	DBL	EBL
		Launch	
Understand the Challenge	Identify content and skills needed to address the driving question.	Focus the problem and understand the design challenge.	
Learn More about the Challenge Context	Consider authentic constraints.	Define the authentic constraints and user-focused criteria.	Consider entrepreneurial opportunities and available resources.
		Design	
Brainstorm, Design, Test, and Refine Solutions	Collaboratively build an artifact that addresses the driving question.	Iteratively design a prototype that meets user criteria.	Design a viable product or service.
Develop the Key Business Proposition		Evaluate design against user-focused criteria.	Define how the product/service creates values for users (clients).
Complete the Technical Brief	Connect project work to intended disciplinary content.	Reflect on the process using a design journal.	Define product specifications for the users (clients).
		Pitch	
Prepare and Practice the Pitch	Give, receive, and incorporate feedback.	Test and expose prototypes to critique.	Practice pitch with external experts.
Deliver the Pitch	Deliver culminating presentation.		Deliver a persuasive pitch to external judges.

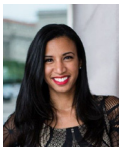
2.4. The D&P Learning Framework Challenges

The D&P Learning Framework includes nine entrepreneurial design challenges targeting middle school mathematics content. The challenges were designed to target a variety of mathematical topics and real-world contexts. The challenge champions were selected to expose students to a diverse range of STEM professionals in hopes that students would be able to see their own identities reflected in the world of STEM and entrepreneurship. Table 2 presents the complete set of middle grades challenges, describing each challenge, its challenge champion, and intended mathematics content.

Table 2. D&P Learning Framework Challenges.

Challenge Title	Description	Champion	
Building Algorithms	Students build algorithms that use people's opinions to rate or rank something they care about. Math Focus: Expressions and Equations		Cathy Yee CEO, Founder, Incluvie
Erase Food Waste	Students design food-related businesses that use sliding price scales to reduce food waste. Math Focus: Percents, Data Analysis		Oscar Ekponimo Founder, CEO Chowberry

Table 2. *Cont.*

Challenge Title	Description	Champion
Fix It: Design for Community Impact	Students design physical products that will help solve a problem facing their communities. Math Focus: 3-D Figures, Surface Area, Volume	Gitanjali Rao Inventor, STEM Promoter
Flashy Fashion	Students design wearable technology products that use LED lighting systems. Math Focus: Transformations, Coordinate Plane	 Kelsy Dominick Designer, CEO DiDomenico Design
Keep It Real	Students design apps that use data representations to help people put down their phones and connect, face-to-face. Math Focus: Data Analysis and Representation	Dr. Cardell PatilloExecutive Director, Head StartProgram
Operation Lifeline	Students design medical packs that can be used to deliver refrigerated medications in times of natural disasters. Math Focus: 3-D Figures; Surface Area, Volume	Kris Ludwig Scientist, US Geological Survey
Pollution Solution	Students design containers, made from dissolvable or edible materials, to package and sell liquid products. Math Focus: 3-D Figures, Surface Area, Volume	Clifford Okoth Owino Founder, CEO Chemolex
Power Me Up	Students design companies that make it easier for people to charge their electric vehicles. Math Focus: Ratios, Data Analysis, Equations	Kristin Vicari Senior Chemical Engineer, Tesla
Prototype to Profit	Students build business plans and pitches to make existing product ideas economically viable. Math Focus: Building Linear Functions, Solving Linear Equations	Tyler Maloney Materials Science Engineer, Entrepreneur

2.4.1. Contexts

The D&P challenges are situated within real-world contexts selected to be accessible to students and open enough to allow them to pursue innovative and authentic solutions using the intended mathematics content. As described in Table 1, the set of D&P challenges targets a variety of contexts that address current and pressing issues. These include environmental contexts, such as pollution, food waste, and emissions from gas-powered vehicles (Pollution Solution, Erase Food Waste, and Power Me Up); economic contexts focused on how to make innovative solutions financially viable (Prototype to Profit); social contexts, such as finding solutions to problems facing one's community and delivering medical supplies following a natural disaster (Fix It: Design for Community Impact and Operation Lifeline); and technological contexts, such as understanding bias in rating algorithms, reducing smartphone dependence, and designing tech-infused fashion (Building Algorithms, Keep It Real, and Flashy Fashion).

Each challenge is situated within an authentic driving question relating to a broad context, such as the new application of a technology, or a multi-dimensional, thorny, and global problem, such as plastic pollution or climate change. Addressing these questions requires one to identify manageable and solvable local opportunities. In the D&P Learning Framework challenges, students are given the autonomy to identify those necessary and personally meaningful local opportunities and capitalize on them in ways that meet the criteria of the challenge and the needs of the people most in need of a solution. In this way, the contexts are engaging and accessible, allowing students to meaningfully draw on their personal interests and experiences in building their entrepreneurial and mathematical solutions. For example, the Flashy Fashion challenge is situated within the broad context of infusing LED technology in fashion. Students have the autonomy to identify opportunities that can be addressed using this technology. In one particularly powerful example, students drew on their experiences wearing masks during the COVID-19 pandemic, specifically the challenge of reading someone's emotions when a mask prevents one from reading facial expressions. To solve this problem, the students designed programmable facemasks that would allow the wearer to show a facial expression using LED lights. They identified and addressed a personally meaningful problem within the broader context of technology-infused fashion.

2.4.2. Champions

Each challenge includes a challenge champion who launches the challenge and gives background information about the context. The champions represent a diverse collection of STEM and entrepreneurial professionals, whose work is closely connected to their challenge and context (see Table 2 above). They provide students with authentic examples of how pursuing solutions to personally meaningful and relevant problems can lead to STEM-focused careers. For example, in the Erase Food Waste challenge, students use sliding price scales to tackle food waste. The champion for this challenge is Oscar Ekponimo. Ekponimo is the CEO of Chowberry, an app that reduces food waste by connecting food-insecure customers with grocery stores looking to sell soon-to-expire foods at a discount. Ekponimo's work inventing the app and convincing grocery stores to offer discounts provides students with a real-world example of the work they are doing in the challenge.

The challenge champions also provide students with a powerful entrepreneurial lens for thinking about career paths. Often, students express interest in working in well-known careers without a complete understanding of the nature of those careers (Mann et al., 2020). Through the stories of the challenge champions, students are exposed to examples of people who built careers around solving problems that they found meaningful. For example, in the Building Algorithms challenge, students are introduced to Cathy Yee, the founder and CEO of Incluvie, a company that rates movies based on their treatment of diversity. Yee found a personally meaningful problem (the movie industry's inaccurate and harmful representation of groups who have been marginalized) and built a career around solving it.

2.4.3. Mathematics Content

Just as the challenge contexts and champions were intentionally designed to represent a diverse range of options, the challenges were also designed to target a diverse range of mathematics content (see Table 2). Middle grades mathematics standards changed significantly with the release of the Common Core State Standards for Mathematics (Confrey & Krupa, 2012). As such we intentionally wrote challenges to align with the six mathematical domains of the Common Core: Ratio and Proportional Reasoning, the Number System, Expressions and Equations, Functions, Geometry, and Statistics and Probability. While each challenge focuses on one mathematical topic, many of the challenges have the

potential for students to engage with multiple mathematical concepts as they build their solutions. For example, in Power Me Up, students are tasked with designing a business that expands the electric vehicle charging infrastructure. The challenge primarily targets ratio and proportional reasoning as students compare the refueling costs of electric vehicles and gas-powered vehicles to determine pricing. Students must also create a prototype plan for where they will build their initial set of charging stations, requiring them to analyze data to determine the locations of existing charging stations and identify gaps. The intended mathematics is woven into the challenge criteria such that building the solution creates a need for students to engage with and develop a deeper understanding of the intended mathematics.

2.4.4. Technology Tools

The D&P Learning Framework includes technological tools with each challenge to support students' prototyping efforts. These freely available online tools were selected based on their utility for building the desired prototype and their ability to support and enhance the intended mathematical reasoning. For three of the challenges (Fix It: Design for Community Impact, Operation Lifeline, and Pollution Solution), the technology tool is TinkerCAD (Autodesk, 2025). TinkerCAD is a 3-D modeling tool that can be used to create 3-D designs by combining and manipulating (e.g., moving, rotating, resizing) figures. It helps students visualize 3-D figures from multiple perspectives, while also attending to the relationships between the features of their designs and the volume and surface area of those designs.

For three other challenges, the technological tool is a spreadsheet. Like with TinkerCAD, the spreadsheet tool (Excel and Google Sheets are both supported) provides students with a way to build a functioning prototype of their solutions, which include rating/ranking algorithms (Building Algorithms), sliding price scales (Erase Food Waste), or a component of financial business plans (Prototype to Profit). The spreadsheet is also a powerful tool for helping students develop a nuanced understanding of variables, algebraic expressions, and functions (Belcher et al., 2024; Filloy et al., 2007; Rojano, 1996; Tabach et al., 2008).

Two challenges (Flashy Fashion and Power Me Up) use GeoGebra (2025) to help engage students with geometric transformations and properties of circles. GeoGebra is an online, dynamic geometry tool that allows students to construct and transform figures. Students use the tool to create transforming fashion (Flashy Fashion) or plan the locations of their charging stations (Power Me Up). The tool allows students to offload the work of manually constructing and transforming geometric figures, which allows them to attend to the properties of those constructions and transformations.

Finally, Keep It Real includes the data representation tool, Datawrapper (Datawrapper GmbH, 2025), which students can use to input data and explore and manipulate different visual representations of that data. Like TinkerCAD and GeoGebra, Datawrapper allows students to offload the task of manually building data representations and instead focus their attention on how changing a representation can alter the story it communicates to an audience. Across the nine challenges, the technological tools not only enhance the authenticity of students' mathematics learning but also enable students to engage deeply with the intended mathematics content.

3. Discussion

This paper presented the components of the D&P Learning Framework, highlighting how it integrates and, through that integration, enhances features of PBL, DBL, and EBL to create distinct opportunities for mathematics learning and engagement. The framework was created to support the learning and application of specific and standards-aligned

mathematics content. The design of the D&P Learning Framework drew on a constructivist perspective of learning, in which students, in response to a perceived problematic (Confrey, 1991), iteratively build, test, and refine models of a given situation. Throughout this iterative process, students continuously reflect on the viability of their models (von Glasersfeld, 1982) and the problematic they are working to address (Confrey & Maloney, 2007; Dewey, 1938/1981). As they progress through this cycle, students develop a deeper understanding of both the problematic they are working to address and the mathematics underlying their solutions (Confrey & Maloney, 2007). By combining features of PBL, DBL, and EBL, the D&P Learning Framework supports and enhances this iterative cycle for students in several important ways that are instructive for STEM education.

First, the D&P Learning Framework demonstrates that an interdisciplinary STEM challenge situated within an entrepreneurial pitch competition can engage students in rich, curricular-aligned mathematics content. One critique often leveled at these types of context-situated STEM challenges is that they sacrifice conceptual rigor for contextual authenticity (Brantlinger, 2022). Students, in their efforts to invent solutions authentic to the real-world context, will either not attend to the targeted mathematics content at all or will engage with the math only superficially. This is especially true for integrated STEM activities, which often lessen the cognitive demand of mathematics (Forde et al., 2023). Although this is a potential limitation, the D&P Learning Framework was designed to address this limitation through its inclusion of design criteria aligned to specific middle grades mathematics content standards. Each challenge was written to include specific design criteria that draw on targeted curricular mathematics content from the six domains of middle grades mathematics: ratios and proportional relationships, the number system, expressions and equations, functions, geometry, and statistics and probability (National Governors Association Center for Best Practices, Council of Chief & State School Officers [CCSSO], 2010). These criteria increase the likelihood that students will engage with the intended mathematics while allowing them to pursue innovative and personally relevant entrepreneurial solutions. However, more work is needed to understand how to better support teachers and students to maintain focus on the intended mathematics content and ensure that students' use and understanding of it deepens throughout the course of a challenge. This work could improve the scalability of the D&P Learning Framework by helping teachers see its value for supporting mathematics learning and feel comfortable implementing a challenge with their students.

Second, by prioritizing the authenticity and entrepreneurial viability of solutions during brainstorming and prototyping, the framework broadens and deepens students' participation in authentic mathematical reasoning, beyond what is typical of middle grades instruction. Each challenge is situated within a broad context and authentic driving question, and students must work collaboratively to identify and address personally relevant entrepreneurial opportunities within that context. Students must draw on their out-of-school interests, knowledge, and experiences to find the entrepreneurial opportunity for which they possess the unique resources to address. This positions students as the experts and equips them with real-world insights that help sustain their engagement, take pride in their accomplishments during a challenge, and deepen their mathematical reasoning. By encouraging students to draw on their deep knowledge of the context and the opportunity they identify, the D&P Learning Framework engages them in essential mathematical activities. This can include defining constructs, creating or selecting appropriate representations, finding measurements of irregular figures, or defining and operationalizing hard-to-measure variables. DBL and EBL's emphasis on users and customers, respectively, establishes a purpose that drives these considerations and provides a lens for self-evaluating their progress. By positioning them as both designers and users, the D&P Learning Framework empowers

students to take responsibility for making mathematical decisions, determining whether those decisions meet the requirements of the challenge, context, and users, deciding when iteration is needed, and defending and justifying their decisions to both external audiences and their teammates.

Third, team diversity and collaboration are essential characteristics of successful entrepreneurship that create opportunities for all students to contribute meaningfully during a competition. Combined with the fast-paced experience of participating in a week-long pitch competition, the D&P Learning Framework requires all students on a team to work collaboratively to design, justify, and pitch an innovative solution to the math-focused challenge. In this way, the D&P Learning Framework leverages entrepreneurship to provide a method for encouraging and supporting meaningful collaboration in a mathematics classroom.

Finally, the expectation that students frequently expose their ideas to critique through teacher check-ins, expert check-ins, the practice pitch, and the culminating pitch creates opportunities for them to reflect on the relationship between the real-world viability of their solution and its underlying mathematics. Communicating ideas is a malleable skill that is foundational to mathematics learning (Gutiérrez, 1999; Herbel-Eisenmann et al., 2013; Moschkovich, 2002). As students practice explaining and justifying their solutions, they become better at doing so, developing a deeper understanding of the solution and the mathematical considerations that informed its design (Warshauer, 2015). Additionally, as their understanding of their solution improves, students become more invested in the solution and more willing to engage with their teachers and the external experts as peers. This investment makes the final pitch, an entrepreneurial twist on the culminating presentation, an appealing opportunity for students to share their unique creations with an external audience. It also provides an immediate and high-stakes purpose that helps students sustain their engagement as they use every opportunity leading up to the competition to continue to practice explaining, justifying, and refining their reasoning.

4. Conclusions

If we recognize the importance of preparing students to tackle thorny, multidisciplinary problems, educators need to develop a variety of curricular innovations to support them in gaining the skills necessary to do so. For too long, we have neglected such preparation, and made questionable claims that such competency will naturally and developmentally be gained by using "structure of the discipline" (Bruner, 1960, p. 20) approaches. As expectations for a broader accumulation of skills and knowledge increase, and students and teachers experience the fatigue of the curricular gallop, the protective reaction is to restrict entry to new approaches and to try, like the sorcerer's apprentice, to do more and more with less and less satisfaction and effectiveness. Ironically, substantial content is repeated each year from the previous year due to the ineffectiveness of the current approaches, thus exacerbating the problem and increasing the self-imposed vicious cycle.

Today's culture is fast-paced, interactive, and constantly changing. Students are accustomed to highly engaging activities and learning informally, through dialogic exchange, how to master and use new features of technology. Their tolerance for dull and repetitious practice is low, and yet, when invited to participate in activities with rapid feedback and motivating contexts, they jump at the opportunity. Mathematics teachers must be supported to break out of the tyranny of content coverage in order to excite students and capitalize on this new reality.

In science education, many schools and districts have embraced learning frameworks intended to motivate the learning of disciplinary content through engaging real-world contexts, including project-based learning (PBL), design-based learning (DBL), and entrepreneurial-based learning (EBL). Mathematics education has been slow and reluctant

to adopt many of these situation-based approaches, and by doing so, has convinced too many students of its irrelevance to their future aspirations. This has led too many teachers to underestimate students' capabilities. To get students to persist in studying mathematics and pursuing careers requiring depth and conceptual knowledge, teachers need to believe in students' ability to reason and problem solve.

In this paper, we introduced an innovative approach (the D&P Learning Framework) that leverages and synthesizes key features of PBL, DBL, and EBL for use in mathematics classrooms, offering novelty through their integration within a single cohesive framework. We also described the nine challenges developed as part of the D&P Learning Framework to show the depth and breadth of the mathematical content that can be included in such an approach. We are not suggesting that the entire mathematics curriculum be taught in this manner, but we do argue for the value of multiple occasions to experience this approach to learn or apply select mathematics concepts. The D&P Learning Framework situates mathematics learning within compelling projects, design challenges, and contexts that are socially and personally relevant to students and call for meaningful social actions. We have observed teachers adapt the framework for a variety of use cases, including as a summative application at the end of an instructional unit, as the primary activity to support the learning of new content, or the launch of community and norm building at the very beginning of the school year. The breadth and openness of the challenges and contexts leave space for taking a variety of approaches, which interjects a key element of design into the solutions. The entrepreneurial framing of the activities grounds students' solutions, positioning them to take on the perspective of a client or consumer and demonstrate economic viability through the development of business proposals.

To support teachers, many of whom are unlikely to have participated in an entrepreneurial pitch competition, this paper provides a description of the processes and practices involved in entrepreneurial design activities and the D&P Learning Framework. The D&P Learning Framework was described as involving three major components (launching the challenge, designing a possible solution, and pitching that solution to a panel of judges). The approach was illustrated with one example, Pollution Solution, and included an overview of the eight other challenges developed as part of the D&P Learning Framework. The complete set of nine challenges encompasses a diverse array of contexts, careers, and professionals (challenge champions). The challenge champions who introduce each challenge, discussing how they built careers around solving similar challenges, show students that their unique experiences have value in the mathematics classroom and that STEM careers are attainable and can be built around inventing solutions to meaningful and thorny problems.

The second part of the framework describes the process of designing a solution and framing it in the context of a business. It involves periods of brainstorming, mutual critique, search for further knowledge of the topic, and the preparation of a Technical Brief to explain the related mathematics. Students must also consider how to make the solution actionable by defining a viable business plan. This requires them to consider what they are proposing, how to accomplish it, and how to market it to potential customers. Relating their proposed solutions to people around them can be an eye-opening experience that not only drives iteration and innovation but also creates opportunities for students to assume new perspectives that they may have previously taken for granted.

Finally, the students prepare and deliver their pitches in five minutes. They must learn to be collaborative in this effort, clearly outline their ideas with figures and graphs, and figure out how to get the attention of the judges to make their ideas pop. It is remarkable how well one has to understand the mathematics of a solution when under time pressure and the scrutiny of judges and peers. Watching students get excited about their ideas, learn

to speak mathematics fluently with each other, access resources to learn more, build their case, and then act as an audience to their classmates is an opportunity that can add to the ways to revitalize mathematics instruction.

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Abbreviations

The following abbreviations are used in this manuscript:

STEM	Science, Technology, Engineering, and Mathematics
PBL	Project-Based Learning
DBL	Design-Based Learning
EBL	Entrepreneurial-Based Learning

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