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# Bridging Theory and Practice: A DRIPBL Model for Enhancing Innovation, Entrepreneurship, and Experiential Learning in Engineering Curricula

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# “Bridging Theory and Practice: A DRIPBL Model for Enhancing Innovation, Entrepreneurship, and Experiential Learning in Engineering/STEM Curricula”

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**Abstract**

A persistent challenge in engineering and science education is the theory-practice gap, wherein students demonstrate conceptual mastery yet struggle to define validated problems, generate credible evidence, and produce innovation outcomes that resemble engineering or entrepreneurial practice. DRIPBL (Dream, Research, Innovate, Problem/Project-Based Learning) is presented as a structured pedagogical framework designed to bridge this gap by integrating creativity, research rigor, and experiential learning. The DRIPBL program was implemented as a co-curricular, nine-month experiential learning initiative for high school students in grades 9-12, engaging 693 students across multiple cohorts from 2021–2024. Five cohorts from ACP High School, enrolled in Honors STEM Research, Biotechnology I and II, AP Environmental Science, and AP Biology, were evaluated over three academic years. DRIPBL guides learners from problem discovery and contextual awareness (Dream), through literature review, experimentation, and data-driven validation (Research), to iterative design and solution development under real-world constraints (Innovate), leading to hands-on execution and dissemination through Problem/Project-Based Learning. Program outcomes included participation and awards at school fair, AzSEF and ISEF, student-authored grants, and research manuscript submissions and acceptance. Analyses revealed a significant interaction between the academic year and DRIPBL inclusion tier ($p < 0.047$), with students in higher-tier DRIPBL participation achieving significantly greater grant funding per applicant in 2023-2024 ($p < 0.013$). These findings indicate that DRIPBL effectively supports innovation capacity, research engagement, and theory–practice integration beyond traditional classroom assessment. The program provides a replicable, evidence-informed model for advancing innovation-ready STEM education in high school settings.

Keywords: DRIPBL, Project Based Learning, Experiential Learning, Entrepreneurship Education, Innovation in STEM

## Introduction

Student passion and curiosity integration matters to the Entrepreneurship and Engineering Innovation community because a critical challenge in pre-college and undergraduate STEM education is the lack of repeatable, evidence-based models that guide students through the ideation process to validated solutions. A persistent challenge in engineering and science education is the "theory–practice gap," widely recognized in recent literature as an unresolved dilemma and "persistent social problem" [1]. While many programs encourage creative brainstorming, few provide structured pathways for students to rigorously practice theory and frame problems, gather and analyze data, develop prototypes, and communicate results effectively as young as 6th graders.

Research suggests that reliance on "textbook-style" problems often creates a "perceived disconnect" for students, who require open-ended, real-world constraints to bridge the divide between classroom instruction and professional application [2]. Without such frameworks, promising ideas often remain conceptual exercises rather than actionable innovations, leaving students underprepared for entrepreneurial practice or professional engineering contexts. This gap is defined as a situation where theoretical knowledge cannot be translated into practice or is not relevant nor applicable to real life conditions" [1], [3], [4], [5]. It represents a disconnect between "what we know we should do" (theory) and " what we actually do"(practice) [6]. This phenomenon is often characterized as an "implementation gap," where knowledge cannot be effectively translated into action due to a lack of contextual training [7], [8], [9].

The community benefits from models that integrate creativity, research, iterative design, and experiential problem solving into a scaffolded, reproducible pipeline by helping future community leaders develop real-world problem-solving skills [10]. By codifying stages that define a scaffolded pipeline where students are encouraged to think beyond textbooks, educators can reliably cultivate students' ability to validate ideas, produce tangible solutions, and communicate outcomes, providing observable indicators of innovation and entrepreneurship [11]. Scalable and repeatable models are essential not only for classroom efficacy but also for advancing evidence-based pedagogy, informing assessment, and supporting longitudinal research [12], [13], [14]. Providing students with structured, hands-on experiences that mirror professional innovation cycles strengthens the pipeline of future engineers and entrepreneurs while creating transferable practices that can be adopted and adapted across institutions and educational contexts [15], [16], [17].

Further, exposure to a variety of ways to address the complexity of problem solving by using project based, hands-on learning rather than a single uniform assignment or lecture-based assignments highlights the reality that dealing with real-world systems can be "tedious and at times frustrating" [2] but also crucial to learning and is often omitted when solely learning theory alone [4]. In essence, DRIPBL (Dream Research Innovate Problem/Project Based Learning) is a solution to the persistent 'theory-practice gap' that exists across diverse fields, including science, engineering, management, math, and technology [1], [4]. This method not only stays restricted to Project Based Learning( PBL) but also stimulates students mindset to integrate other aspects of foundational project development skills, supports designing ethical and impactful research projects, helps the students in integrating storytelling in analysis and visualization of the data, concluding and communicating the journey from research to delivery and also supports students in scientific writing and submission of their projects in peer reviewed journals.

In our study of the effectiveness of DRIPBL methodology in a classroom setting, we have taken the approach that the relationship between theory and practice is bidirectional and are equally important as practical application generates new questions and reinforces theoretical understanding [4]. There are other ways that we could frame our approach to closing this gap using active learning techniques (like student led field work) etc. Though overall, the DRIPBL model encompasses a holistic approach to closing this gap and providing a hands-on, empowering experience allowing students to drive the process of their own learning using their strengths and weaknesses in a structured way and make them understand that failure is only a stepping stone for research and innovation.

We investigated the following three research questions in various STEM high school courses between 2021 and 2024:

- RQ1 (Evidence & Student Outcomes)
  How does a stage-gated DRIPBL co-curricular pipeline effect patterns in student outcomes, such as competition participation, grant writing, and publication, across cohorts with differing levels of exposure to the DRIPBL curriculum?
- RQ2 (Scalability & Program Implementation)
  What instructional, mentoring, and organizational strategies support the scalable implementation of the DRIPBL model for students in other academic settings?

**Conceptual Framework: DRIPBL**

The conceptual framework positions the DRIPBL pipeline as a structured, repeatable model for transforming student ideas into validated innovation outputs and strengthening their high school portfolio for college applications. Students enter the framework with creativity, curiosity, and little to no STEM knowledge, generating initial problem notions that are often unstructured. These ideas are guided through four sequential stages: <u>Dream</u>, where students identify meaningful challenges and engage in divergent thinking; <u>Research</u>, where they conduct literature review, patent searches, market analysis of available products in that field, experimentation, and data-driven validation; <u>Innovate</u>, where iterative design, prototyping, and feasibility analysis occur; and <u>Problem/Project-Based Learning</u>, where solutions are implemented, tested, refined, and communicated.

Each stage includes a feedback loop that reinforces iteration, problem validation, and evidence-based reasoning. Observable outputs such as prototypes, research reports, patents, scholarships, success in student competitions, TEDx talks, and publications serve as program-level indicators of experiential learning and entrepreneurial readiness. The framework emphasizes the development of key competencies, including problem formulation, design and prototyping, data analysis, teamwork, and professional communication, while providing measurable signals of theory-to-practice integration. By linking inputs, structured processes, feedback, and tangible outputs, this framework offers the Entrepreneurship and Engineering Innovation community *a scalable, evidence-informed model for cultivating students' ability to* *transform ideas into validated, impactful solutions*. In this paper, data based on metrics like competition success, research paper submission in high school journals and acceptance, and the amount of scholarship money received by the students in the cohorts are presented and discussed.

**Program Description (9-month co-curricular pipeline, (N=693)**

This research paper on the effectiveness of the copyrighted DRIPBL program, a co-curricular, nine-month experiential learning initiative for high school students in grades 9–12, engaged a total of 693 students across multiple cohorts from 2021–2024. The DRIPBL curriculum is a novel Project-Based Learning (PBL) program developed by Nath [18] to strategically engage students in meaningful research experiences. The DRIPBL pipeline as a structured, repeatable framework, uses stage gates and milestone deliverables (1.) A completed research project, (2.) Competition in a science and engineering fair(s), and (3.) Research paper completion and peer-reviewed submission that includes grant writing and TEDx talk applications by students) to guide students from early curiosity to validated, communicable innovation outputs. The program units (below) are scaffolded into instructional modules, aligned with DRIPBL stages and milestone deliverables:

- Unit 1: From Curiosity to Question — Foundations of Scientific Research & Project Development. Students learn how to translate curiosity into researchable questions and scope projects around meaningful, real-world problems.
- Unit 2: Designing Impactful Research Projects - Emphasizes research ethics, responsible conduct, stakeholder considerations, and societal impact.
- Unit 3: Analyzing, Visualizing & Telling the Story Through Data. Students focus on data collection, analysis, visualization, and evidence-based storytelling to support validation and decision-making.
- Unit 4: Concluding & Communicating the Adventure-Conclusions, Abstracts, and Presenting Projects. Guides students in synthesizing findings, writing conclusions and abstracts, and preparing professional presentations, posters, and pitches.
- Unit 5: Post-Competition Publication -Writing, Reflection, & Next Steps. Supports students in converting projects into publications, patent or competition submissions, structured reflection, and planning future research or entrepreneurial pathways.

Together, the DRIPBL stage-gated pipeline and modular instruction create a repeatable, scalable model that moves students from ideas to validated evidence, functional prototypes, and professional communication outputs mirroring authentic engineering, research, and entrepreneurial practice. Out of the 693 students across all years, some repeated the HSR class in multiple years, and some DRIPBL students were concurrently enrolled in other courses, such as AP Biology, when they wrote their grants.

**Instructional/mentorship support framework**

To operationalize this model, DRIPBL combined cohort level instruction with small group participation capped at 15 students per year, using a first-come, first-served enrollment process to minimize selection bias.

This enrollment cap is necessary because, unlike traditional courses, the instructor must provide individualized guidance for each student project, whether in sustainability, engineering, bioinformatics, biomedical fields, or marketing/sociology. As a result, the course does not follow a single standardized curriculum applicable to all students simultaneously. All students are given an equal opportunity to enroll during the registration period, reducing barriers that might otherwise limit participation to only academically strong students.

This course is also offered as a dual-enrollment option, providing 3 college credits for BIO 297 (Research) through Missouri Southern State University. This designation makes it comparable in rigor to AP courses and further reduces bias in the types of students who choose to participate. Any student in grades 9–12 with an interest in curiosity-driven projects can join the class on a first-come, first-served basis. Each cohort begins with an introduction to core DRIPBL concepts, stage gates, and milestone deliverables, establishing a shared foundation in research, innovation, and problem-based learning. Students may then choose to work individually or in small mentoring groups of up to three, allowing for collaborative preparation for competitions. Each project receives personalized support for scoping, experimental design, prototype development, and communication.

Feedback from Subject Matter Experts (SMEs) ranging from industry professionals to academic researchers enabled validation, refinement, and iteration of student work in real time, supported by structured guidance on how to engage effectively with SMEs. This layered model balances broad instructional touchpoints with individualized guidance, ensuring consistency and rigor while fostering creativity, research skills, iterative design, and entrepreneurial readiness, central to the DRIPBL experience.

**Methodology:**

Five cohorts of students from Arizona College Preparatory High School (ACPHS) were enrolled in Honors STEM Research [HSR], featuring a fully flexible curriculum, Biotechnology 1 and 2 which are 60% laboratory based and allow partial research integration; and Advanced Placement Environmental Science (APES) andAdvanced Placement Biology (APBIO), both of which followed rigid schedules that limit opportunities for student led research; Table 1).

Class sizes for HSR were capped at 15 students, compared to a maximum of 30 students for other courses Data were collected over three consecutive academic years (2021-2022, 2022-2023, and 2023-2024). Yearly enrollment varied as follows: HSR: 8-15 students; Biotechnology 1: 49-62 students; Biotechnology 2: 20-33 students; APES:14-30 students; and APBIO: 81-141 students (each course offered in multiple sections of up to30 students).

Students in these courses were evaluated using multiple metrics, including qualifying and placement in the Arizona Science and Engineering Fair (AzSEF) and the International Science and Engineering Fair (ISEF), the number of students who applied for and received grants, and the number of students submitting research papers for publication versus those accepted. Courses were categorized into DRIPBL implementation fidelity tiers based on the extent, consistency, and structural integration of the DRIPBL pipeline over the three years: Tier 1 = full implementation, Tier 2 = partial implementation, and Tier 3 = no implementation.

Table 1: Shows the categorization of the different fidelity tiers based on implementation characteristics and duration of the program.

| Implementation Tier | Course Cohorts | Curriculum Exposure | Duration | Mentor Effort (Per Student) | Key Characteristics |
|---|---|---|---|---|---|
| **Tier 1: High Fidelity** | Honors STEM Research (HSR) | **Full** | Full Year | **120 min / week** | Sustained, total integration of all DRIPBL phases. |
| **Tier 2: Moderate Fidelity** | Biotechnology 1 & 2 | **Partial** | One Quarter | **30 min / week** | Scaffolded implementation of specific elements. |
| **Tier 3: Low/No Fidelity** | AP Environmental Science & AP Biology | **None** | N/A | **10–15 min / week** | Minimal to no formal alignment with DRIPBL. |

**Data Analysis Methodology:**

Statistical analyses and figure generation were performed using JASP* [19].

Model 1. ANCOVAs on School Fair participation and winning rates. Purpose: to assess the association between DRIPBL implementation and student participation, controlling for differences in class size.

Dependent variable: logit of School Fair participation rate, defined as p fair = # of students at School Fair divided by # of students in class. To stabilize variance and approximate normality, analyze y = logit(p_fair) = log((p_fair + c) divided by (1 − p_fair + c)), using a small continuity correction c = 0.5 divided by n where n is the class size, so rows with 0 percent or 100 percent participation remain usable. Fixed factor: DRIPBL Curriculum with three levels Tier 1, 2, 3. Covariate: # of students in class. Rationale: Participation is a proximal engagement outcome not determined by later competition stages. Adjusting for class size is important because raw counts scale with class size. The model was repeated for each dependent variable: 1.) # of students who qualified for AzSEF, 2.) # of students who won at AzSEF, 3. # of students who qualified for ISEF, 4. # of students who won at ISEF

Model 2. ANOVAs to assess professional grants awarded and publications per student, including both participants and applicants. Purpose: to compare programs on competitive grant writing and publication outcomes while accounting for differences in class size and student participation.

Dependent variable 1: log of per student grants awarded, defined as y = log((Total # of Grants awarded / # of students who applied) + 1). The +1 handles zeros. Dependent variable 2: Student Participation %, defined as y= ((# of students who participated in writing grants or publications/# of students in class)*100). Fixed factor: DRIPBL Inclusion Tier. Optional sensitivity: include Year as a fixed factor if residual diagnostics remain acceptable and there are enough degrees of freedom. We will do a similar analysis for publications.

**Results:**

I. Science and Engineering Fair Participation and Winning Results.

Across all analyses, DRIPBL Inclusion Tier (Table 1) consistently emerged as a strong predictor of student success at the school, state (AzSEF), and international (ISEF) Science and Engineering Fair levels over three consecutive years.

Table 2: Student Qualification and Award Percentage (%) by DRIPBL Implementation Fidelity Tiers in school, state (AzSEF) and International (ISEF) science and engineering competitions. Mentor effort per student is defined per tier grouping.

| Fidelity Tier | Course Cohorts | Mentor Effort (Per Student) | School Fair (%) | Qualified to State (%) | Won at State (%) | Won at ISEF (%) |
|---|---|---|---|---|---|---|
| Tier 1: High | Honors STEM Research | 120 min / week | 100.0% | 100.0% | 73.5% | 26.5% |
| Tier 2: Moderate | Biotech 1 & 2 | 30 min / week | 27.2%* | 23.1%* | 6.2%* | 2.8%* |
| Tier 3: Low/No | AP Bio & AP Env. Sci | 10–15 min / week | 4.2%* | 3.15%* | 1.55%* | 0.15%* |

School Fair → AzSEF Outcomes.

As shown in Figure 1A, DRIPBL Inclusion Tier significantly predicted the proportion of students who qualified for AzSEF after adjusting for class size, $F(2,10) = 18.547$, $p < 0.001$, partial $\eta^2 = 0.79$, while class size was not significant, $F(1,10) = 0.761$, $p = 0.404$. Tier 1 classrooms showed markedly higher qualification rates than both Tier 2 ($p_{Tukey} = 0.017$) and Tier 3 ($p_{Tukey} = 0.001$), with no meaningful difference between Tiers 2 and 3 ($p_{Tukey} = 0.126$). Similarly, Figure 1B shows that Tier also predicted AzSEF win rates, $F(2,10) = 15.781$, $p < 0.001$, partial $\eta^2 = 0.76$, again with class size nonsignificant, $F(1,10) = 0.003$, $p = 0.960$. Tier 1 students won at substantially higher rates than Tier 2 ($p_{Tukey} = 0.004$) and Tier 3 ($p_{Tukey} = 0.002$), whereas Tiers 2 and 3 did not differ ($p_{Tukey} = 0.759$). These patterns align with Table 2, in which Tier 1 students show the highest AzSEF advancement and win percentages.

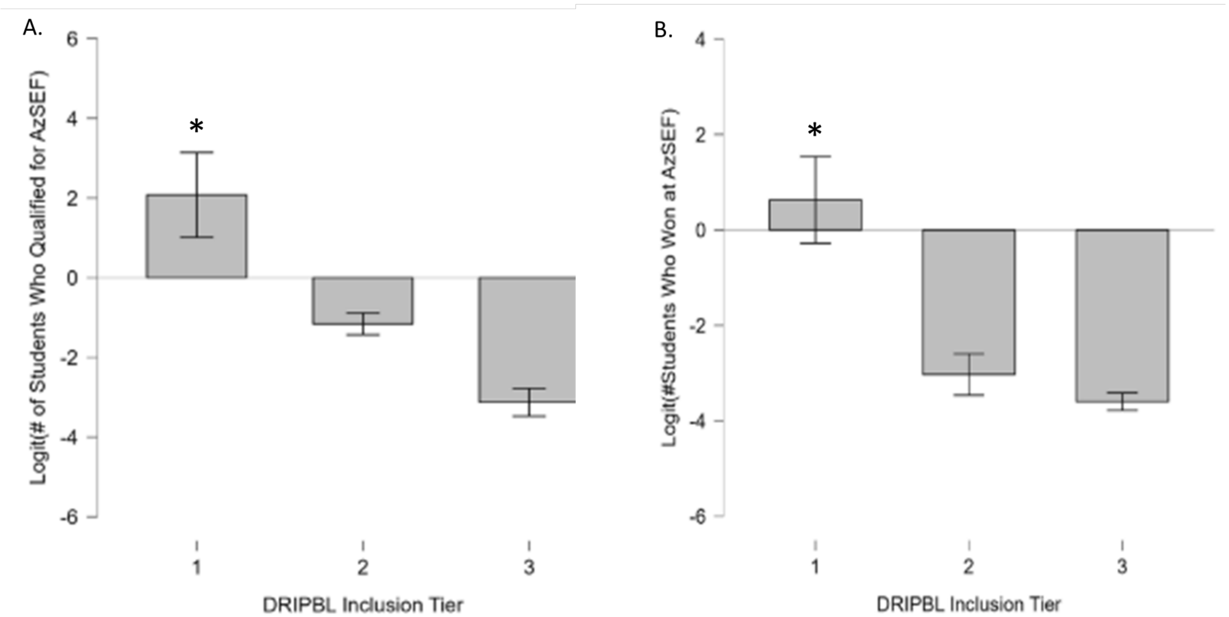


Figure 1: Panel A. After adjusting for class size, DRIPBL Inclusion Tier significantly predicted the proportion of students who qualified for AzSEF. Tier 1 classrooms showed substantially higher qualification rates than Tier 2 and Tier 3, consistent with ANCOVA results indicating a strong main effect of DRIPBL Inclusion Tier, $F(2,10) = 18.547$, $p < 0.001$, partial $\eta^2 = 0.79$, while class size was not significant, $F(1,10) = 0.761$, $p = 0.404$. Tukey post hoc tests confirmed that Tier 1 outperformed Tier 2 ($p = 0.017$) and Tier 3 ($p = 0.001$), with no significant difference between Tier 2 and Tier 3 ($p = 0.126$). Panel B. DRIPBL Inclusion Tier also significantly predicted the proportion of students who won at AzSEF, controlling for class size, $F(2,10) = 15.781$, $p < 0.001$, partial $\eta^2 = 0.76$, with class size again nonsignificant, $F(1,10) = 0.003$, $p = 0.960$. Adjusted means showed the highest win rates for Tier 1, followed by Tier 2 and Tier 3. Tukey comparisons indicated that Tier 1 had significantly higher win rates than Tier 2 ($p = 0.004$) and Tier 3 ($p = 0.002$), with no significant difference between Tier 2 and Tier 3 ($p = 0.759$).

Progression to the International Level (ISEF).

Figure 2.A shows that DRIPBL Inclusion Tier also significantly predicted ISEF qualification rates when controlling for class size, $F(2,10) = 14.840$, $p = 0.001$, partial $\eta^2 = 0.75$. Unlike the AzSEF models, class size was a significant covariate, $F(1,10) = 5.691$, $p = 0.038$. Adjusted means revealed the same directional pattern: Tier 1 > Tier 2 > Tier 3. Post hoc tests indicated Tier 1 qualification rates were significantly higher than Tier 2 ($p_{Tukey} = 0.015$) and Tier 3 ($p_{Tukey} = 0.013$), while Tier 2 and Tier 3 did not differ ($p_{Tukey} = 0.915$).

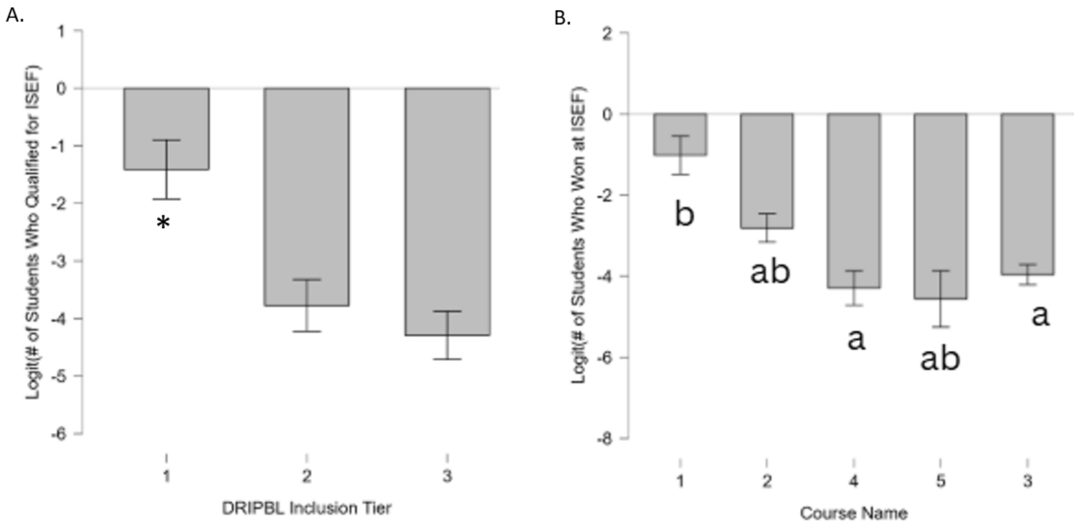


Figure 2.A. DRIPBL Inclusion Tier significantly predicted the proportion of students qualifying for ISEF after adjusting for class size, $F(2,10) = 14.840$, $p < 0.001$, partial $\eta^2 = 0.75$. Class size also contributed significantly to variation in qualification rates, $F(1,10) = 5.691$, $p = 0.038$. Tier 1 (full DRIPBL implementation) showed the highest adjusted qualification rates, outperforming Tier 2 ($p = 0.015$) and Tier 3 ($p = 0.013$), while Tiers 2 and 3 did not differ ($p = 0.915$).

Figure 2.B. Course significantly predicted ISEF win rates when controlling for class size, $F(4,8) = 17.213$, $p < 0.001$, partial $\eta^2 \approx 0.90$, with class size also significant, $F(1,8) = 8.937$, $p = 0.017$. Because qualification perfectly predicted wins *($R^2 = 1.00$, $p < 0.001$),* all students who advanced to ISEF received a placement or special award. Tukey HSD letter groupings (based on $p_{Tukey} < 0.05$) indicated that HSR (1) had the highest adjusted win rates (b), Biotech 1 (2) and AP Biology (4) were intermediate (ab), and AP Environmental Science (5) and Biotech 2 (3) had significantly lower win rates (a).

Course-Level Predictors of ISEF Wins.

As shown in Figure 2.B, course type strongly predicted ISEF win rates after adjusting for class size, $F(4,8) = 17.213$, $p < 0.001$, partial $\eta^2 \approx 0.90$, with class size again significant, $F(1,8) = 8.937$, $p = 0.017$. A preliminary regression indicated perfect prediction between ISEF qualification counts and ISEF wins *($R^2 = 1.00$, $p < 0.001$)*, demonstrating that every student who qualified ultimately earned either a placement or a special award. Tukey HSD comparisons grouped courses by adjusted win rates, with Honors STEM Research (HSR) highest, Biotech 1 and AP Biology intermediate, and AP Environmental Science and Biotech 2 lowest.

Together, these results show a clear pattern: higher-fidelity Tier 1 are strongly linked to higher qualification and win rates at every level of competition, from school fairs to international stages.

II. Student Professional Grants and Publications Results

Across all analyses, DRIPBL Inclusion Tier (Table 1) emerged as a strong and consistent predictor of student grant and publication participation and awards/acceptance.

Student Grant Writing & Success

When we tested how the number of student grants written compared to those awarded we found a significant interaction between Year and DRIPBL Inclusion Tier, two-way ANOVA: $F(4, 5) = 5.387$, $p = 0.047$; Figure 3). This indicates that there were differences in grants awarded per applicant across tiers over time (Figure 3.B). Although this interaction was significant, follow-up Tukey HSD tests did not identify significant pairwise differences, likely due to limited statistical power and variability within groups (Figure 3).

Table 3: Total number of students in each tier and the number of grant participation and grants won by different tiers across three years of the study.

| Fidelity Tier | Total Students | Students Who Wrote Grants | Grant Participation Rate (%) | Grants Won |
|---|---|---|---|---|
| Tier 1: High | 34 | 32 | 94.1% | 15 |
| Tier 2: Moderate | 214* | 5* | 2.3% | 5* |
| Tier 3: Low/No | 445* | 0* | 0.0% | 0 |

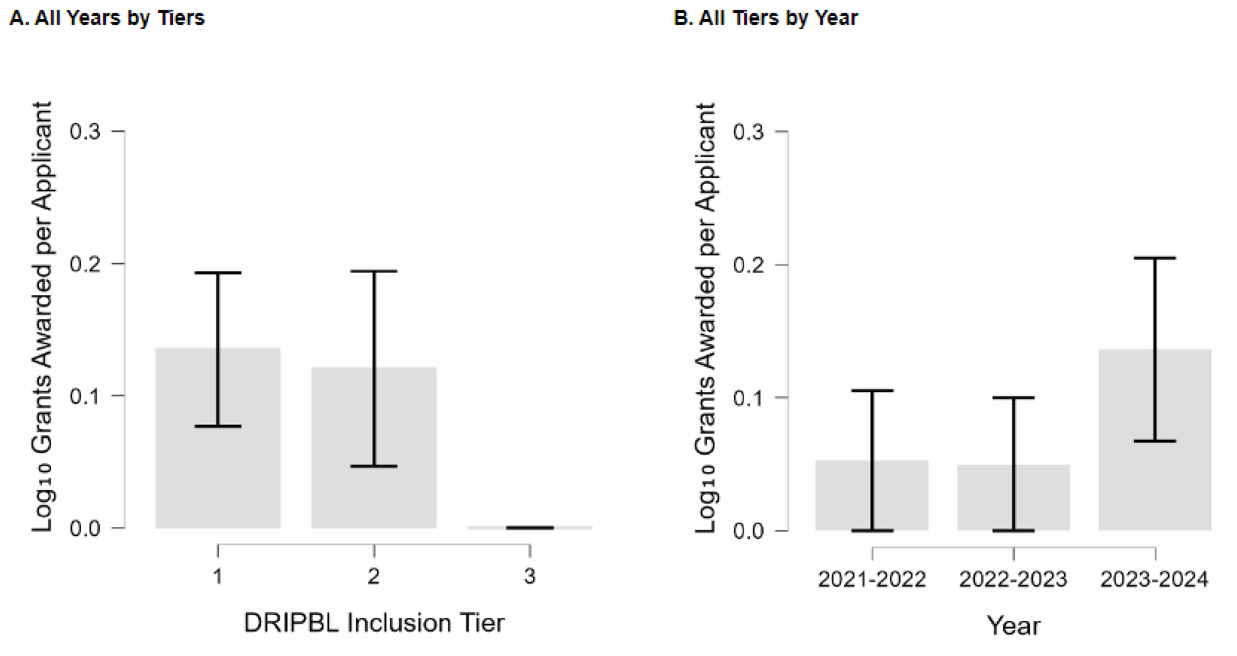


Figure 3. Panel A. Estimated marginal means of $\log_{10}$ grants awarded per applicant as a function of DRIPBL Inclusion Tier. Panel B. Estimated marginal means of $\log_{10}$ grants awarded per applicant as a function of Year. Two-way ANOVA testing effects of Year and DRIPBL Inclusion Tier of those students awarded/applied resulted in a significant Year × Inclusion Tier interaction ($p = 0.047$), indicating that differences among tiers varied across years ($F(4, 5) = 5.387$, $p = 0.047$). Despite this interaction, post hoc Tukey HSD comparisons were not statistically significant, reflecting limited power and variability within individual pairwise contrasts.

Though, when we tested whether grant writing participation percent differed by DRIPBL Inclusion Tier the effect was significant (one-way ANOVA: $F(2, 11) = 10.92$, $p = 0.002$; Table 3). Tukey post hoc tests showed Tier 1 had a much higher participation rate (94.1%) than Tier 2 (2.3%) (mean difference = 67.99, SE = 16.80, $t = 4.05$, $p_{Tukey} = 0.005$) and Tier 3 (0%) (mean difference = 70.45, SE = 16.80, $t = 4.19$, $p_{Tukey} = 0.004$). Tiers 2 and 3 did not differ (mean difference = 2.46, SE = 15.84, $t = 0.16$, $p_{Tukey} = 0.987$). These results indicate Tier 1 participants engaged in grant writing far more than those in Tiers 2 or 3 (Table 3). The trend of students from Tier 3 courses (AP Biology and AP Environmental Science) not attempting grant writing was consistent across years (Table 3 and Figure 3).

Student Publication Writing & Acceptance Success

Raw data included in these analyses are included in Table 4. Across the three years examined, multiple courses had periods with no publication submissions. In 2021–2022, Biotech 1, AP Biology, and AP Environmental Science submitted no manuscripts; in 2022–2023, Biotech 1, Biotech 2, and AP Environmental Science had no submissions; and in 2023–2024, AP Environmental Science and AP Biology again had no submissions.

Table 4. Number of Student Research Papers Submitted and Accepted for Peer-Reviewed Publication by DRIPBL Curriculum Tier (2021–2024)

| Fidelity Tier | Total Students | Research Papers Submitted | Research Papers Accepted | Acceptance Rate |
|---|---|---|---|---|
| **Tier 1 - High Fidelity (HSR)** | 34 | 12 | 12 | **100.0%** |
| **Tier 2 - Moderate Fidelity (Biotech 1 & 2)** | 214 | 5 | 4 | **80.0%** |
| **Tier 3 - Low/No Fidelity (AP Bio & AP Env. Sci)** | 445 | 2 | 2 | **100.0%** |

To investigate how student publication writing and acceptance success varied, we first tested $\log_{10}$ publication acceptance per submission by DRIPBL Inclusion Tier, Year was excluded in this test to conserve degrees of freedom. An omnibus one-way ANOVA was not significant, $F(2, 11) = 1.667$, $p = 0.233$, indicating no reliable differences among tiers at the group level (Figure 4.A). Table 4, shows that Across Fidelity Inclusions Tiers, acceptance rates were uniformly high: Tier 1 and Tier 3 both achieved a 100% acceptance rate, while Tier 2 showed a slightly lower but still strong acceptance rate of 80%. Taken together, the pattern suggests that while the tiers do not differ significantly from one another, there was a high instance of acceptance when students submitted to peer-reviewed journals.

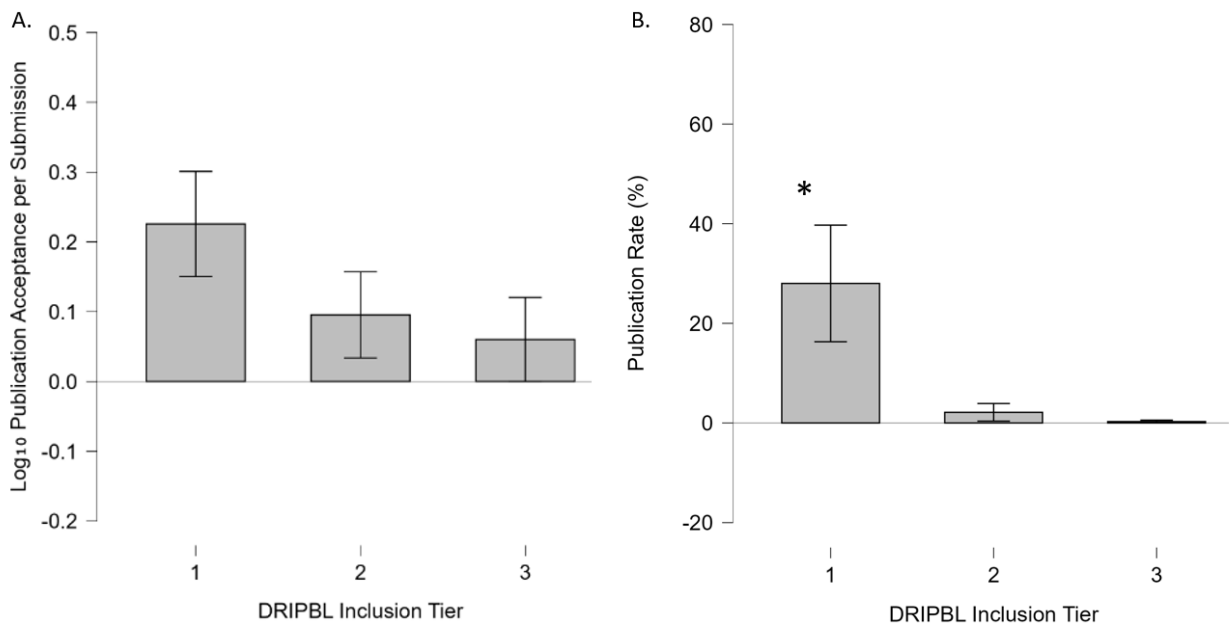


Figure 4: Panel A. Mean $\log_{10}$ publication acceptance per submission across DRIPBL Inclusion Tiers (bars = estimated marginal means; standard error bars). A one-way ANOVA showed no overall difference among tiers, $F(2, 11) = 1.667$, $p = 0.233$. An exploratory marginal-means test against zero indicated Tier 1's mean was positive (0.226; 95% CI [0.028, 0.424], $t(11) = 3.218$, $p = 0.025$), whereas Tier 2 and Tier 3 were not different from zero (Tier 2: 0.095, 95% CI [-0.082, 0.272], $p = 0.470$; Tier 3: 0.060, 95% CI [-0.117, 0.237], $p = 1.000$) with a Bonferroni CI adjustment. Panel B. Publication rate (%) as a function of DRIPBL Inclusion Tier with standard error bars. Tier 1 showed a significantly higher publication rate than Tier 2 and Tier 3, one-way ANOVA: $F(2,11) = 6.64$, $p = 0.013$, with Tukey tests indicating Tier 1 outperformed Tier 2 ($p_{Tukey} = 0.025$) and Tier 3 ($p = 0.017$), while Tiers 2 and 3 did not differ ($p_{Tukey} = 0.970$).

Secondly, we investigated further how the Student Publication Rate (number of published papers ÷ total students) was influenced by DRIPBL Inclusion Tier (Figure 4.B). An one-way ANOVA showed a significant effect of Inclusion Tier on Publication Rate, $F(2,11) = 6.64$, $p = 0.013$. Tukey tests indicated Tier 1 had higher publication rates than Tier 2 (mean difference = 25.87%, $p_{Tukey} = 0.025$) and Tier 3 (mean difference = 27.73%, $p_{Tukey} = 0.017$), while Tiers 2 and 3 did not differ (mean difference = 1.86%, $p_{Tukey} = 0.970$).

## Discussion

I. Science and Engineering Fair Participation and Winning Results.

The above results and analysis on the three Tier cohorts across three years of data shows significant differences in the three metrics studied in this paper, the competitive results of students in science and engineering competitions, research grants written and research paper submission and acceptance. The data had to be normalized as there were discrepancies in the number of students who went through the different tiers as depicted in table 1. The results are discussed here to explain DRIPBL's impact on Tier 1 versus Tier 2 and Tier 3 students.

DRIPBL methodology enforces evidence-backed innovation: students must "Research" before "Innovate," then must execute via PBL to claim impact [15], [16], [17], [20], [21]. Analysis of the above results from 693 students across 3 years over 5 different subjects with three different tiers of DRIPBL Instructional model clearly indicates a significant improvement of student per that are performing at a 100% success rate in applying for competitive events with 73% success rate at the state and 26% at the international level as compared to 9.3% and 4.2% for partial instruction and only 2.7% and 0,2% at the international level competitions (Figures 1.A ( $p < 0.001$) , 1.B ($p < 0.001$, 2.A ($p < 0.001$) and 2.B ($p < 0.001$)). These results show significant differences of the DRIPBL Tier 1 curriculum with Tier 2 and Tier 3 in all the three indicators for Science competitions, papers published and also the grant writing and grant received over the three year period studied.

II. Student Professional Grants and Publications Results

Across all grant-writing and publication outcomes, a clear and consistent pattern emerged: students in Tier 1 (high-fidelity DRIPBL implementation) demonstrated substantially greater engagement and productivity than those in Tier 2 or Tier 3 ($p = 0.002$). Tier 1 students participated in grant writing at far higher rates and were the only group to consistently generate both grant submissions and awards across years, whereas Tier 3 students showed a repeated pattern of non-participation. (Figure 3.A and 3.B, $p= 0.013$). For publications, although acceptance rates were uniformly high whenever students submitted work, Tier 1 was the only tier with reliably high submission and publication rates relative to overall enrollment (Figure 4.A and 4.B $p = 0.013$). Combined, these patterns indicate that high-fidelity DRIPBL implementation is strongly associated with sustained student participation and success in grant writing and publication activities.

Above results show that DRIPBL Framework, if replicated as a Tier 1 program in academic institutions, has the capability to accelerate STEM learning methodologies much more impactfully than following the traditional ways of teaching STEM [21], [22]. Expansion capacity can grow through a hierarchical mentoring system that blends whole-group "teaching the teacher" model with focused small-team guidance and occasional specialist consultation.

From an administrative standpoint, aligned scheduling, small class sizes, unified materials for concept clarification, and transferable lesson frameworks enabling creativity and belief in student dreams enabled the program to engage participants while maintaining commitment to core DRIPBL principles for Tier 1 students. Growth occurred not through amplifying teaching contact hours but through creating reproducible processes over three years of study, establishing clear role boundaries, and building upon existing educational materials. These methods indicate that supplementary project-driven initiatives can expand effectively by prioritizing procedural transparency and shared responsibility over exclusive reliance on personalized teaching approaches [23],[24].

III. Student Anecdotal Feedback:

Qualitative feedback from end-of-year reflections corroborated these outcomes from HSR. Students consistently reported gains in confidence, independent problem formulation, collaboration, time management, and perseverance [11]. Many described concrete milestones such as refining research questions, improving communication skills, and presenting original work, highlighting meaningful engagement with authentic STEM practices. One student noted, "The DRIPBL curriculum ignited a deep passion for STEM within me. It motivated me to continue pursuing a career as a physician-researcher, where I can contribute to advancements in healthcare and make a positive impact."

Students also emphasized the development of practical skills, including writing grants, submitting proposals, and managing project timelines. While some noted challenges with workload or self-directed tasks, these were largely perceived as opportunities to build resilience and ownership. Collectively, these reflections demonstrate that DRIPBL supports not only academic and technical outcomes but also personal growth and professional preparedness, reinforcing the program's effectiveness beyond traditional classroom measures.

**Conclusion**

Returning to the two research questions for the paper,

- RQ1 (Evidence & Student Outcomes)
  How does a stage-gated DRIPBL co-curricular pipeline effect patterns in student outcomes, such as competition participation, grant writing, and publication, across cohorts with differing levels of exposure to the DRIPBL curriculum
- RQ2 (Scalability & Program Implementation)
  What instructional, mentoring, and organizational strategies support the scalable implementation of the DRIPBL model for students in other academic settings?

The nine-month co-curricular DRIPBL pipeline structures student innovation through sequential phases, Dream, Research, Innovate, and Problem/Project-Based Learning, that guide students from initial problem identification to project execution and communication. The paper provides ample proof of RQ1.Observed and targeted innovation outputs include student participation in research and engineering competitions, grant proposal submissions, development of validated project artifacts or prototypes, and preparation of abstracts or manuscripts for dissemination along with practice skills of presentation, body language determination of judges during competitions and understanding the skillsets that enables a wholesome development of a student far beyond academics. Each of the 5 units mentioned in the methodology of this paper, is supported by defined milestones, feedback loops, and revision checkpoints, enabling consistent delivery of design and critical-thinking processes across cohorts while accommodating variation in project focus and disciplinary context to motivate each and every student. These outputs are treated as indicators of engagement with research, design, and communication practices rather than as evidence of causal impact.

As for RQ2, as described in the discussion, we will strengthen analytic rigor by refining and aligning achievements across pipeline stages, standardizing artifact collection and documentation procedures, and formalizing study design and analysis methods across various. These methods indicate that supplementary project-driven initiatives can expand effectively by prioritizing procedural transparency and shared responsibility over exclusive reliance on personalized teaching approaches. Results from these efforts are intended to support a future full-length paper with clear construct alignment, more systematic evidence collection, and improved reproducibility.

The DRIPBL framework demonstrates scalability across multiple educational levels and institutional models. At the K–12 level, extracurricular school clubs provide a flexible environment for transdisciplinary, open-ended projects integrating science, technology, arts, design, culture, and sports. These programs can be modeled after successful initiatives like the Lemelson-MIT program, which distributes curriculum, materials, and professional development to students and teachers. At the higher education level, DRIPBL can be embedded in university capstone courses. While ABET-accredited programs widely employ project-based learning [10], DRIPBL introduces a structured, stage-gated methodology that explicitly integrates entrepreneurship, prototype validation, and research dissemination, helping students achieve high-fidelity outcomes such as grant proposals and peer-reviewed publications. Finally, to enable widespread adoption, DRIPBL can be scaled institutionally through formal curriculum licensing and bundled offerings, combining curriculum materials with aligned professional learning services into co-branded packages that simplify procurement and implementation across schools and universities.

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## References


[1] E. Arteaga, R. Biesbroek, J. Nalau, & M. Howes, "Across the great divide: A systematic literature review to address the gap between theory and practice" *Sage journals, 14*(1), *2024.* https://doi.org/10.1177/2158244024122

[2] S. Ouhbi, "Bridging the theory–practice gap in a maintenance programming course: An experience report", Proceedings of the 46th International Conference on Software Engineering: Software Engineering Education and Training, pp. 359–367, April 2024. https://doi.org/10.1145/3639474.3640062

[3] Bhagavatula, L., Garzillo, C., & Simpson, R, "Bridging the gap between science and practice: An ICLEI perspective", *Journal of Cleaner Production, 50*, 205–211, July 2013. https://doi.org/10.1016/j.jclepro.2012.11.024

[4] Greenway, K., Butt, G., & Walthall, H. (2019). What is a theory–practice gap? An exploration of the concept. *Nurse Education in Practice, 34*, pp 1–6, 2013. https://doi.org/10.1016/j.nepr.2018.10.005

[5] A. Hewison & S. Wildman, "The theory–practice gap in nursing: A new dimension. *Journal of Advanced Nursing", 24*(4), pp. 754–761, 1996. https://doi.org/10.1046/j.1365-2648.1996.25214.x

[6] A. T. Knight, R. M. Cowling, M. Rouget, A. Balmford, A. T. Lombard, and B. M. Campbell, "Knowing but not doing: Selecting priority conservation areas and the research–implementation gap," *Conservation Biology*, vol. 22, no. 3, pp. 610–617, 2008. https://doi.org/10.1111/j.1523-1739.2008.00914.x

[7] S. Connelly, S. Markey, and M. Roseland, "Strategic sustainability: Addressing the community infrastructure deficit," *Canadian Journal of Urban Research*, vol. 18, no. 1, pp. 1–23, 2009.

[8] H. Jiang, S. Geertman, and P. Witte, "Avoiding the planning support system pitfalls? What smart governance can learn from the planning support system implementation gap," *Environment and Planning B: Urban Analytics and City Science*, vol. 47, no. 8, pp. 1343–1360, 2020. https://doi.org/10.1177/2399808319887695.

[9] M. M. Magnusson, "Bridging the gaps by including the police officer perspective? A study of the design and implementation of an RCT in police practice and the impact of pracademic knowledge," *Policing: A Journal of Policy and Practice*, vol. 14, no. 2, pp. 438–455, 2020. https://doi.org/10.1093/police/pay022

[10] A. Lavado-Anguera et al., "A systematic review of PBL in engineering using PRISMA," *Education Sciences*, 2024. [Online]. https://www.mdpi.com

[11] A. Schneider et al., "A literature review clarifying how design thinking interfaces with entrepreneurship education," in *Springer Handbook Chapter*, 2023. [Online]. https://link.springer.com

[12] S. Jones et al., "A decade-long results paper on an integrated, first-year STEM research+learning program (SMART)," *Frontiers in Education*, 2023. [Online]. https://www.frontiersin.org

[13] Council on Undergraduate Research, "CUR Transformations," 2016–2024. [Online]. https://www.cur.org

[14] ACS Committee on Professional Training, "Guidance on course-embedded undergraduate research," 2025. [Online]. https://www.acs.org

[15] S. Couch, L. Estabrooks, and A. Skukauskaitė, "Addressing the gender gap among patent holders through invention education policies," *Technology & Innovation*, vol. 19, no. 4, pp. 735–749, 2018. https://doi.org/10.21300/19.4.2018.735

[16] L. B. Estabrooks and S. Couch, "Failure as an active agent in the development of creative and inventive mindsets," *Thinking Skills and Creativity*, vol. 30, pp. 103–115, 2018. https://doi.org/10.1016/j.tsc.2018.02.015

[17] S. R. Couch and M. Z. Kalainoff, "Transforming a national invention education program through a strength-based approach," *TechTrends*, 2024. https://doi.org/10.1007/s11528-024-00953-2

[18] DRIPBL™. Reg. No. 7,692,176. Registered 2023. Rachna Nath as part of DRIPBL STEAM Analytics, LLC.

[19] JASP Team, *JASP (Version 0.95.3) [Computer software]*, 2025. [Online]. https://jasp-stats.org/

[20] H. Kwon and Y. Lee, "A meta-analysis of STEM project-based learning on creativity," *STEM Education*, vol. 5, no. 2, pp. 275–290, 2025. https://doi.org/10.3934/steme.2025014

[21] L. Zhang and Y. Ma, "A study of the impact of project-based learning on student learning effects: A meta-analysis study," *Frontiers in Psychology*, vol. 14, 1202728, 2023. https://doi.org/10.3389/fpsyg.2023.1202728

[22] C. Rodriguez, "Cultivating excellence in education: A comprehensive exploration of the sustained influence of project-based learning on academic achievement - A meta-analysis spanning over 15 years," TTU DSpace Repository, 2025. https://hdl.handle.net/2346/102320

[23] J. Petrokubi, A. Denton, M. Holmgren, and S. Taylor, "Scaling high-quality project-based learning for deeper learning impact," Education Northwest, 2020.

[24] N. Zuckerbrod, "Enabling conditions for scaling project-based learning," Lucas Education Research, 2021.