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Evaluating effectiveness of an inclusive inquiry-based STEM education program on senior high school student performance post-COVID (Evaluation)

Ms. Kimberly Seaman, University of Toronto

Kimberly Seaman is a PhD candidate in the Department of Mechanical and Industrial Engineering at the University of Toronto with a specialization in musculoskeletal sciences.

Charles Lake, University of Toronto
Noor E. Bahsoun, University of Toronto
Ruonan Cao, University of Toronto
Mr. Nicolas Ivanov, University of Toronto

Nicolas Ivanov is a PhD student at the Institute of Biomedical Engineering at the University of Toronto, and a member of the PRISM Lab at Holland Bloorview Kids Rehabilitation Hospital.

Nadia Scharnhorst, University of Toronto
Ms. Nhien Tran-Nguyen, University of Toronto
Zhiyue Zhu, University of Toronto
Dr. Dawn M Kilkenny, University of Toronto

Dawn Kilkenny is an Associate Professor, Teaching Stream in Biomedical Engineering. She is currently the Vice Dean, First Year in the Faculty of Applied Science and Engineering at the University of Toronto.

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Abstract

Secondary school STEM courses implement a knowledge-based approach to learning in contrast to the critical thinking framework in post-secondary education. Subsequently, students often have limited understanding of applying STEM concepts in post-secondary learning environments that demand critical thinking competencies for success. The *Discovery* program was launched in 2016 to engage high school students in applying scientific concepts through inquiry-based STEM projects. Each semester, Grade 11 and 12 students enrolled in biology, chemistry, or physics classes at local high schools undertake an open-ended research project rooted in a real-world problem. Student visits to university teaching facilities occur multiple times throughout the semester with instructional support from graduate student mentors and science teachers, allowing students to explore their interests in STEM using state-of-the-art resources while engaging directly with practicing scientists. The *Discovery* project comprises 10-15% of each student's final course grade.

Prior to the COVID-19 pandemic, the *Discovery* program demonstrated multiple positive outcomes for students. For many participants, performance in their *Discovery* grade significantly exceeded their in-class performance, with 37% of program participants scoring at least 15% higher on their *Discovery* project compared with their overall course grade. However, educational practices have shifted as students and teachers face post-pandemic challenges surrounding learning disruptions that have not been fully defined. In adapting to this new educational landscape, we are investigating whether student impact of the *Discovery* program framework has shifted due to pandemic-related educational effects. In a recent study, thematic analysis of structured interviews with teachers who partnered with *Discovery* in 2024 revealed that while students and teachers are navigating post-pandemic challenges in classroom engagement and learning loss, students are excited and engaged during program participation, promoting development of a more resilience-oriented long-term learning mindset.

Herein, we examine post-pandemic outcomes of the *Discovery* learning model through student performance. Grade, survey, and attendance data from participants collected during Spring and Fall 2025 programming was assessed to define program impact for students. Spring 2025 findings include data representing 82 students from 3 high schools, with each school facing various degrees of external challenges to learning, as determined by the learning opportunities index from the local partner school board. Analysis of quantitative post-pandemic metrics indicated that overall student academic performance is enhanced in *Discovery,* which aligns with pre-pandemic outcomes of the program. Notably, *Discovery* has differential impact on students from schools with different degrees of external challenges to learning. Students from schools with higher degrees of challenges to learning achieved higher grade differentials between course and *Discovery* grades compared to students from a school identified with fewer challenges to learning. Surveys revealed that students carried generally positive attitudes towards *Discovery*

and that the program provided opportunities to address the specific challenges individual students face. Quantitative evidence of post-pandemic learning loss including chronic absenteeism is presented in this study, which revealed that a large proportion of students who excelled in *Discovery* post-pandemic were chronically absent from the classroom. Thus, *Discovery* continues to provide learning impacts for participants similar to those observed prior to the pandemic, while being an accessible platform in which emergent post-pandemic learning challenges can be addressed. The findings from this study provide valuable information for how similar immersive, inquiry-based STEM programs can continue to maintain student benefits post-pandemic.

1. Introduction

The COVID-19 pandemic resulted in unprecedented disruptions to secondary education systems, with prolonged school closures, rapid transitions to remote/hybrid instruction, and reduced access to hands-on learning environments [1]. In science, technology, engineering, and mathematics (STEM) education, these disruptions disproportionately affected experiential learning opportunities that rely on laboratory access, collaborative problem solving, and iterative feedback [2]. As a result, secondary students faced interruptions not only in content coverage but also in development of foundational skills such as scientific reasoning, experimental design, and sustained academic engagement. These losses are particularly consequential in STEM disciplines, where conceptual understanding and skill development are cumulative and depend on repeated practice and feedback [3,], [4].

Emerging post-pandemic research suggests that these disruptions have produced persistent challenges rather than short-term learning gaps. Teachers report challenges related to student engagement, confidence, and preparedness for higher-order scientific thinking, particularly as students return to in-person learning environments following extended periods of disrupted instruction [5], [6]. These challenges are particularly pronounced in senior-level STEM courses, which serve as a bridge between structured, content-driven instruction, and the inquiry-oriented expectations of post-secondary education. Importantly, the magnitude and persistence of these challenges vary across learning contexts, with more pronounced disruption identified for students who attend schools exhibiting greater external barriers to learning [6].

In response to these challenges, there is a growing need to evaluate educational approaches that not only remediate content loss but also support rebuilding of student confidence, engagement, and higher-order thinking. Inquiry-based learning (IBL) has been widely proposed as a pedagogical framework capable of addressing these needs by enabling students to engage in active hands-on learning, develop critical thinking competencies, and collaborate with peers in pursuit of open-ended problems [7]. Prior research has demonstrated that immersive IBL, extending beyond isolated classroom activities to sustained investigation supported by iterative feedback, can enhance conceptual understanding and promote deeper engagement with scientific practice [8]. At the same time, effective implementation of IBL in secondary settings presents practical challenges. Inquiry-driven instruction often requires additional time, instructional support, and access to resources that are not equally distributed or available across schools. Moreover, students may initially struggle with the autonomy and uncertainty inherent to inquiry-driven tasks following extended periods of learning disruption [8], [9].

The *Discovery* program is an immersive, inquiry-based STEM education initiative established through a long-standing partnership between the Faculty of Applied Science and Engineering at the University of Toronto and local secondary schools. Since 2016, the program has allowed for embedded semester-long, open-ended research projects within senior secondary biology, chemistry, and physics courses, allowing engagement of participating students with scientific practice beyond traditional classroom instruction [10], [11]. Specifically, *Discovery* is a collaboration between graduate student mentors and secondary teachers, where mentors provide expertise in scientific investigation and laboratory skills and teachers help shape projects that align with provincial curricular requirements and are accessible for their students [12]. At the same time, the program preserves key features of authentic STEM inquiry, including experimental uncertainty, iterative problem-solving, and student-driven decision-making. Pre-pandemic studies reported strong positive outcomes, including higher student achievement on *Discovery* deliverables compared to conventional coursework, with 37% of participants scoring at least 15% higher on their *Discovery* projects than their classroom grades [10]. Subsequent work documenting the program's transition to virtual and hybrid formats during the COVID-19 pandemic further emphasized the central role of inquiry, mentorship, and iterative learning in sustaining student engagement under disrupted instructional conditions [13].

Despite the reported positive outcomes of *Discovery*, educational programs that were effective prior to the pandemic cannot be assumed to maintain the same impact in post-pandemic learning environments. IBL programs that can integrate curriculum alignment, mentorship, and access to STEM settings, while remaining inclusive and adaptable to diverse student needs, may be highly valuable in the post-pandemic educational landscape. Understanding whether such inquiry-driven programs continue to support student learning, engagement, and equity under evolving conditions is therefore critical for program impact and broader educational practice. As secondary science classrooms continue to adapt to the lasting effects of pandemic-related disruptions, our team re-evaluated *Discovery* program outcomes to better understand how the framework and impact have evolved within this changing educational context [8]. Thematic analysis revealed persistent challenges related to student disengagement, knowledge and skill gaps, as well as increased need for instructional scaffolding [8]. Simultaneously, teachers consistently described *Discovery* as a highly engaging learning environment compared to standard classroom instruction, reporting renewed student interest, increased confidence, and greater willingness to engage in open-ended scientific thinking during program participation [8]. While these qualitative findings underline the continued benefits of immersive inquiry-based programming, understanding whether these shifts in student engagement and learning are reflected through quantitative indicators of student performance and participation across recent program offerings remained undefined.

The present study examined post-pandemic outcomes of the *Discovery* learning model through an analysis of student performance, attendance, and survey responses collected during the Spring 2025 semester. Student *Discovery* grades were compared to course performance to assess whether participation in *Discovery* continues to support learning outcomes distinct from traditional classroom instruction. These analyses were further contextualized by examining differential impact across schools experiencing varying degrees of external challenges to learning and identifying student subsets of interest based on defined criteria. Student performance, engagement, and attitudes towards the *Discovery* program were examined in relation to pre-pandemic metrics of academic performance. Using metrics of student performance from both pre-pandemic and post-pandemic offerings of *Discovery*, we evaluated how identified challenges in post-pandemic classroom engagement have manifested in STEM learning environments. As part of an ongoing evaluation process within the program, this mixed-methods analysis of student outcomes aims to identify program impact on student learning and inform where areas of attention are required to ensure sustained relevance for *Discovery* and similar inquiry-based STEM programs that must adapt to a post-pandemic educational landscape.

2. Methods

2.1 Ethics

All data collection involving students in Spring 2025 was previously approved by the University of Toronto Research Ethics Board (protocol #47071) and the Toronto District School Board (TDSB) External Research Review Committee (protocol #3074328). All data were anonymized by classroom teachers prior to release to University of Toronto researchers to maintain student confidentiality. Parental consent to data collection was obtained prior to the start of programming; academic data for students without parental consent was not collected nor were surveys administered to these students.

2.2 Program structure

Program structure, sample projects, and curriculum development have been presented and discussed extensively [10], [11], [12], [13]. All in-person visits and the final scientific symposium take place on campus within university learning facilities. Participation is free of charge, with graduate mentors volunteering their time to support program activity. All students engage as full-class cohorts from partner secondary schools, distinguishing participation from typical outreach or camp-related programs where students may register individually.

The unique structure of the *Discovery* program (**Figure 1**) aligns with the Ontario high school academic calendar. The program begins with a Skill Lab to introduce students to University of Toronto teaching facilities and allow students to develop the required skills for their discipline-specific project. Students are then presented with a subject-specific Request for Proposal (RFP). In response, students work in groups of 3-4 at their regular classroom to develop a project proposal that includes background research, project scope, a proposed experimental protocol, and a work plan. Discipline-specific *Discovery* mentors and school teachers provide feedback to the students prior to initiation of experimental work. Students execute their proposed protocols and collect preliminary data during Experimental Visit 1. These results are analyzed by students and presented to each group's graduate student mentor during a virtual client meeting. Mentors provide specific feedback during this meeting, and students are encouraged to discuss potential changes to their project protocol. Experimental Visit 2 allows students to execute their updated protocol and collect additional/new data. Students analyze their data to develop evidence-based conclusions and recommendations and create a scientific poster as their final program deliverable. Posters are presented to the university community and undergraduate/graduate student judges at a final on-campus Symposium, where students also have opportunity to engage with an undergraduate student panel regarding the transition to post-secondary STEM programs.

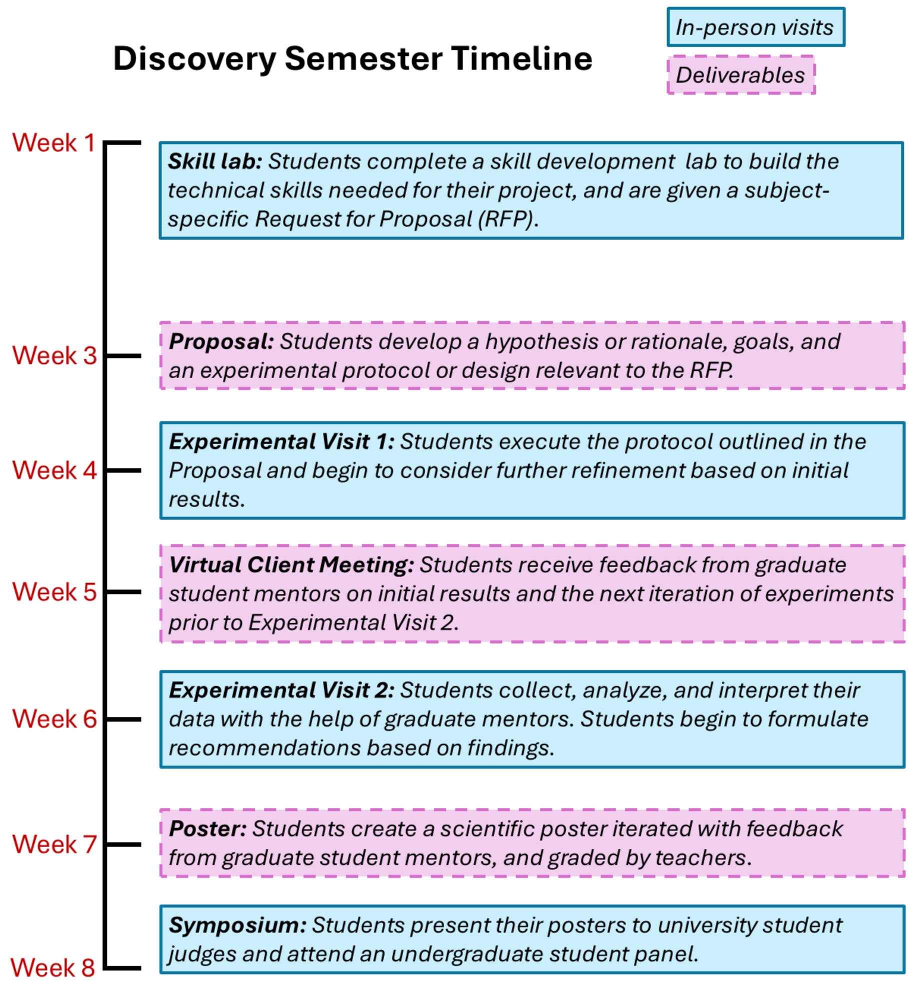


Figure 1. Overview of the timeline for a semester of *Discovery*. Blue boxes with solid outlines represent in-person student work on campus and purple boxes with dashed outlines represent student deliverables.

2.3 Study participants

Data collected during Spring 2025 programming represents Grade 11-12 STEM students (enrolled in Biology, Physics, Kinesiology, or Chemistry; n = 82) from three partner schools; students enrolled in Kinesiology participated in the Physics project. Projects in the Spring 2025 semester included investigation of DNA degradation (Biology), optimization of hydrogels for controlled drug release (Chemistry), and design of a prosthetic limb (Physics).

Participating schools ranked variably on the TDSB Learning Opportunities Index (LOI; **Table 1**). The LOI is a numerical index reflecting the degree of external challenges to student success based on the socioeconomic status of residents within a school's neighborhood [14]. Higher LOI ranking indicates greater external challenges and resource constraints [14]. As of 2023, *Discovery* schools ranked within the second, third, and fifth quintiles on the LOI (i.e., School A faces the highest challenges to learning and greater resource constraints) [14].

Table 1. LOI Distribution of *Discovery* program participants in the Spring 2025 semester

School	Number of participants	LOI quintile
A	19	2nd
B	31	3rd
C	32	5th

Information on pre-pandemic student participants (n = 159), data collection, and results have been disseminated in several previous studies on program outcomes. This population includes students from the Spring 2017, Fall 2017, and Fall 2018 offerings of the program [10], [11].

2.4 Grade & attendance data

Student grade and attendance data from both the classroom components and *Discovery* program were collected as quantitative metrics of academic performance and engagement, *respectively,* to assess the impact of *Discovery* on student learning post-pandemic. Of note, in all participating schools, the specific partner educator within each class was the only assessor of both course and *Discovery* deliverables, enabling a consistent approach to student evaluation. Prior to the Spring 2025 semester, each school had participated at least once in an in-person semester of *Discovery*. Student grade and attendance data collected from the Spring 2025 semester were used to evaluate evolving trends of student outcomes in relation to the pre-pandemic dataset.

2.5 Metrics on academic performance and engagement

Student performance and engagement were quantitatively assessed using final course and *Discovery* grade data, as well as class and *Discovery* absences. *Discovery* outcomes constitute 10-15% of a students' final course grade; therefore, to avoid correlation between program-associated work and in-classroom deliverables, a course grade without the *Discovery* component (hereby referred to as the 'course grade') was computed for direct comparison to the *Discovery* grade. Student deliverables that comprised the *Discovery* grade included the Proposal, the Virtual Client Meeting, and the Poster (**Figure 1**). Pairwise comparisons were made to assess differences between student grades on *Discovery* deliverables versus their course grades (i.e., less the *Discovery* component). To control for inter-school differences that potentially impact and confound grading outcomes (e.g., school grading policies, LOI, etc.), we additionally conducted *Discovery* versus course grade pairwise comparisons separately for each school cohort.

Student academic performance and engagement data were further analyzed to identify various subsets of interest that demonstrate distinct metrics compared to other participants within the Spring 2025 cohort. Student subsets of interest were computed using defined criteria. Specifically, an "Exceeds Expectations" (EE) subset of students was identified; previous studies on student performance in the *Discovery* program defined the EE subset as students who obtain a differential in their *Discovery* grade that is one or more standard deviations above their course grade [10]. The same criterion for the EE subset was applied to the Spring 2025 dataset, noting that one standard deviation in the course grade is 15.71%. In addition to the EE subset, additional analyses were conducted on data from chronically absent (CA) students. We applied the definition for chronic absenteeism in Ontario, which is a student missing 10% or more of class days [15], [16] to identify CA students within pre-pandemic and post-pandemic samples.

2.6 Student Perspective Surveys

Surveys were administered prior to and following programming to discern student attitudes towards the *Discovery* program (n = 82). Students were asked to identify the most challenging facet of the program, to be answered in an open-ended format. Student responses were coded by an unbiased coder not involved in the Spring 2025 semester of programming using an inductive, iterative coding approach. An initial review was performed by the primary coder to generate preliminary codes. Coding proceeded in multiple iterative passes, where the codebook was refined through addition and consolidation of codes to better represent patterns found in student responses. Verification was performed by a second coder, who independently reviewed the generated codes. Identified discrepancies were discussed and resolved, leading to the final coding scheme outlined in **Table 2**.

Table 2. Codebook for extracting identified challenges in *Discovery* participation in the Spring 2025 semester.

Codes	Definition of student-identified challenge
Technical Skills	Technical skills (3D printing, assembling parts)
Limited Resources	Lack of parts/materials or difficulty working with materials and equipment available
Time	Difficulty meeting deadlines/time in lab
Overwhelm (open-ended nature, running into issues)	Feeling overwhelmed at starting/difficulty with iterating when they ran into problems
Poster/Writing/Presentation	Difficulty with writing/developing poster/presenting poster
Analysis	Analyzing data or generating plots
Attendance	Attendance, that getting to campus was difficult
Prosthetic Design	Difficulty with how to make a prosthetic/making it support weight/any other prosthetic-specific design issue
Experimental Design	Difficulty in making a plan
Design	Sum of the Prosthetic Design and Experimental Design categories
Interpersonal	Difficulty with team members
Program Organization	Difficulty with website/instructions/coordination within the program
General or Miscellaneous	Miscellaneous or vaguely described difficulties
Research	Difficulties with research (background research)

Closed-ended survey questions using a 5-point Likert scale were also presented in student surveys to understand perceived student preparedness, challenge of *Discovery*, and comfort with various programming activities. To better understand the evolving impact of *Discovery* compared to pre-pandemic outcomes, the results of close-ended survey questions and grade data (n = 82) were broadly compared to the results found in our pre-pandemic cohort (n = 159).

2.7 Statistical methods

Prior to testing, aggregate student performance and engagement data collected from each school in the Spring 2025 semester were assessed for normality using the D'Agostino and Pearson omnibus test. Student performance and engagement data within each school cohort were also assessed for normality using the D'Agostino and Pearson omnibus test. No group within the aggregate data (course grade, *Discovery* grade) passed the normality test, indicating that non-parametric tests were more appropriate for these data. While the course grade component within each school cohort passed the normality test, remaining groups (*Discovery* grade, class absences, and *Discovery* absences) did not. **Table 3** outlines the statistical tests used for various comparisons in this study.

Table 3. Statistical tests used to compare outcomes between different school cohorts or within-school cohorts

Comparison	Number of groups compared	Statistical test
Course versus *Discovery* grades within a school cohort	2	Wilcoxon matched-pairs signed rank test
Course grades between school cohorts	3	Brown-Forsythe and Welch ANOVA tests followed by Dunnett's T3 multiple comparisons test
Discovery grades, class absences, *Discovery* absences between school cohorts	3	Kruskal-Wallis test followed by Dunn's multiple comparisons post-hoc test
Compare grades between student subsets of interest (e.g., EE versus non-EE)	2	Mann-Whitney U-test

An Analysis of Covariance (ANCOVA) was performed to determine if the slopes of the two regression lines were significantly different between student subsets. If the difference between slopes was determined as insignificant, the intercepts were tested for significance. If the difference between slopes was determined to be significant, the difference between intercepts was not tested further. All statistical analyses were performed on GraphPad Prism 10. Statistical significance for all tests was taken at $\alpha = 0.05$.

3. Results and discussion

3.1 Analysis of Spring 2025 student performance data

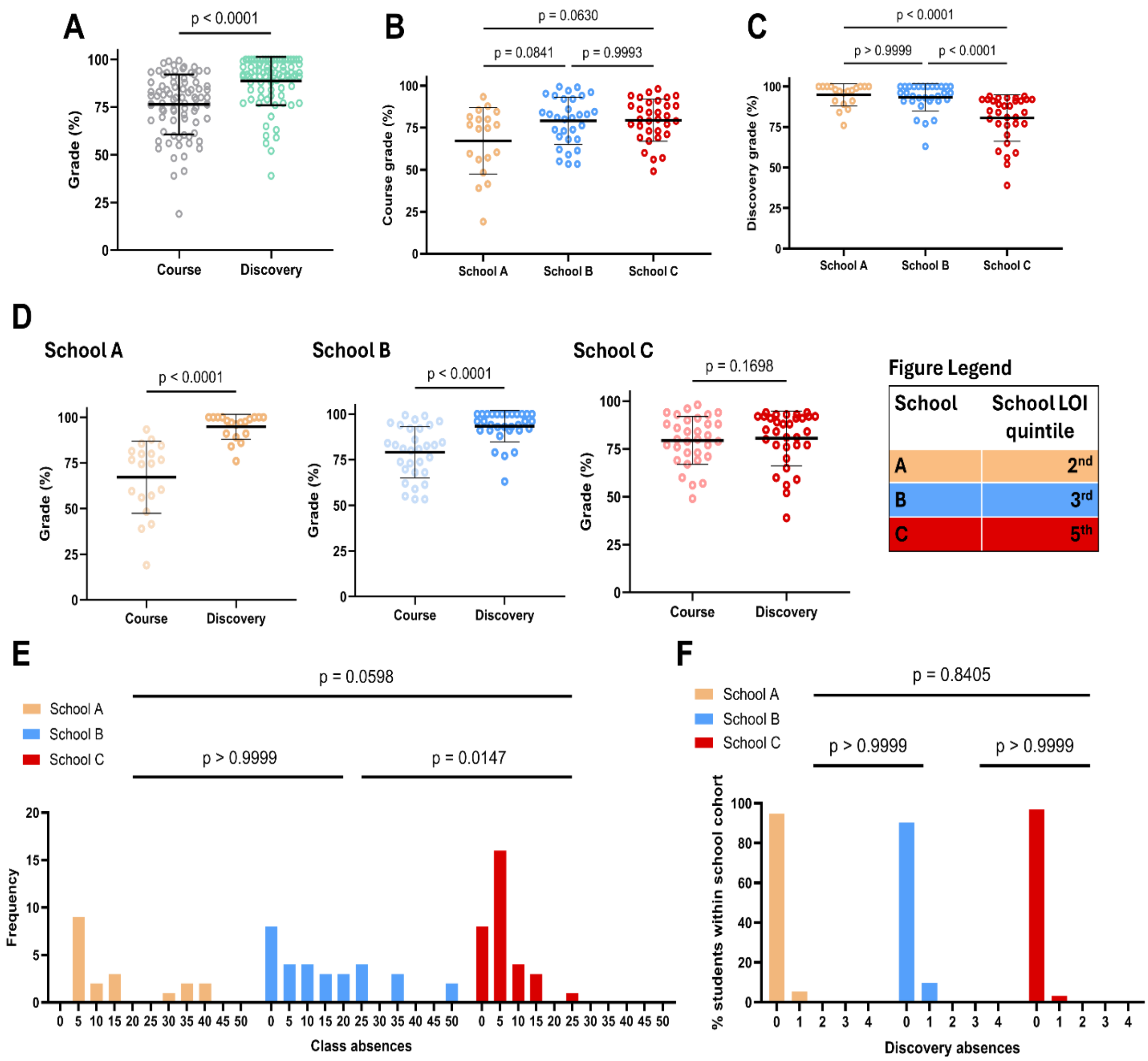


Figure 2. Student grade and attendance data in the *Discovery* program and classroom, shown as either aggregate data or separated by school cohort. (A) Course and *Discovery* grades from the Spring 2025 semester. (B), (C) Course (excluding *Discovery* deliverables) and *Discovery* grades for each school, *respectively*. (D) Comparisons of course versus *Discovery* grades are shown for Schools A, B and C. (E) Frequency histogram of classroom absences across schools. (F) Percentages of *Discovery* program absences across schools. Figure legend shows the LOI quintile for each school. P-values reflect a non-parametric Kruskal-Wallis H-test between schools followed by a post-hoc Dunn's test for multiple comparisons. P-values for comparisons within the same school cohort reflect Wilcoxon tests. Significance was determined if p < 0.05 in all comparisons.

Holistically, student grade and attendance data suggest that *Discovery* continues to positively impact student learning and engagement post-pandemic (**Figure 2**). A comparison between aggregate course and *Discovery* grades indicated that students achieved significantly higher grades in *Discovery* (**Figure 2A**). However, this outcome was not persistent across all three schools (**Figure 2D**), with only students from Schools A and B (higher LOI rankings/greater resource constraints) achieving *Discovery* grades that significantly exceeded their course grades (by an average of 27.7% and 14.3%, *respectively)*. Comparisons of the distributions of course grades (**Figure 2B**) and *Discovery* grades (**Figure 2C**) between schools revealed (i) no significant differences between course grades and (ii) higher *Discovery* grades in Schools A and B relative to School C.

Similarly, significant differences were observed in classroom absences between students in Schools A, B, and C. The median number of class absences for individual students was higher for the School A and B cohorts than for the School C cohort (**Figure 2E**). A Kruskal-Wallis H-test followed by Dunn's post-hoc tests indicated that the number of classroom absences for individual students was significantly higher in School B compared to School C. While the same post-hoc comparison between Schools A and C did not reach significance, it is notable that School A had multiple students with a high number of absences (30+) and no students with zero class absences, whereas School C had only one outlier student with a high number of absences and several students with zero absences. In contrast to these inter-school differences, no significant differences were observed in *Discovery* attendance between schools. Furthermore, absences for *Discovery* program days across all schools were very rare (**Figure 2F**).

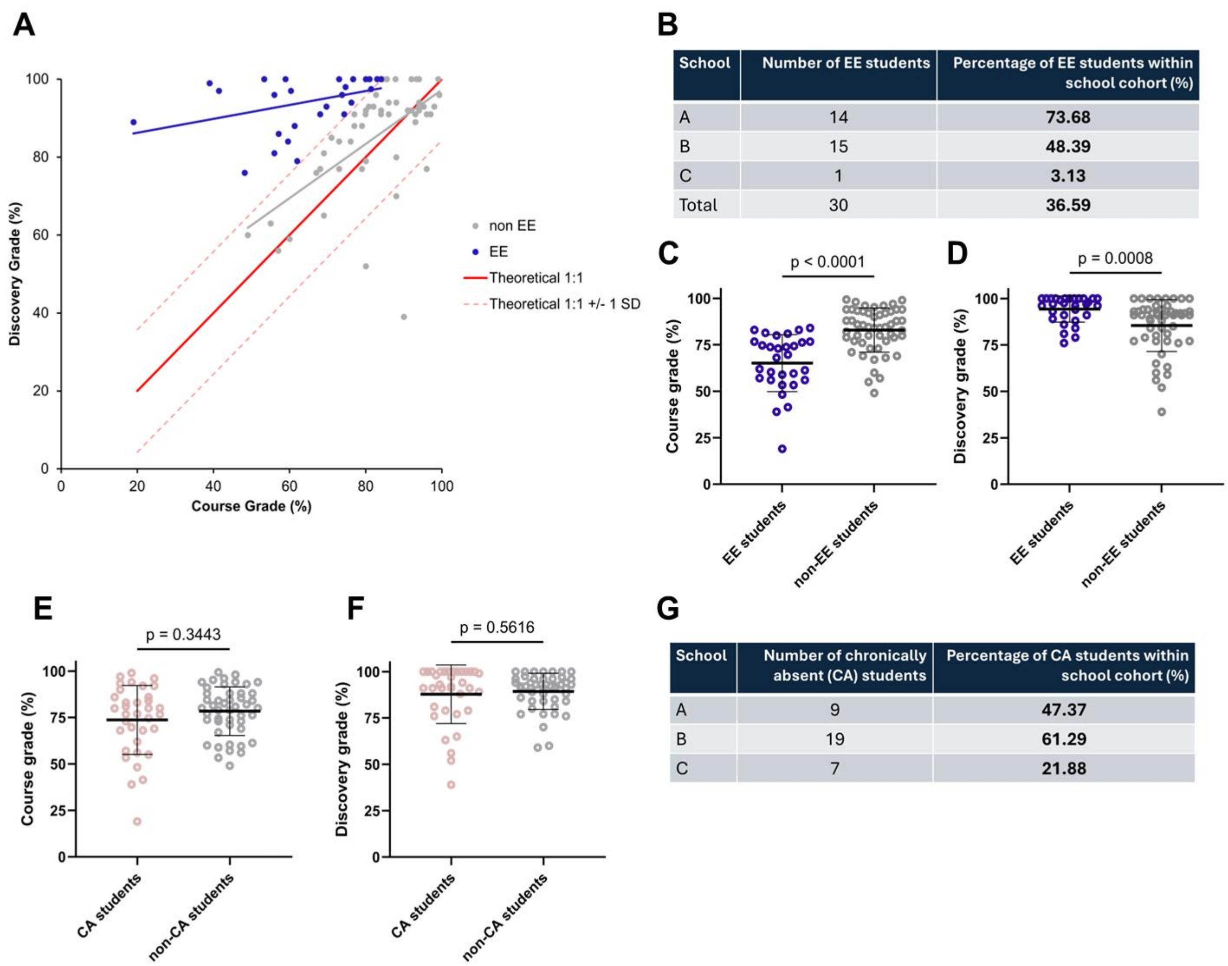
Taken together, the grade and attendance results suggest differential impact of *Discovery* program participation on the students from the different schools in this study. The observed trends in academic performance and engagement (i.e., higher grades and fewer absences in *Discovery* versus regular course instruction/assessment) and the differences in these outcomes between schools within similar LOI quintiles are consistent with pre-pandemic *Discovery* program evaluations [10], [11], [13].

In our previous study, the higher impact of the *Discovery* program on students from higher LOI schools was attributed to different cultures of learning found at each school [13]. These different cultures of learning were created by school resource availability and students' approach to learning, thereby influencing student attitudes towards *Discovery* and the value that students from each school would ascribe to the program [13]. Furthermore, it was speculated that students from higher LOI schools were more likely to have previously honed the skills from external circumstances to persevere through challenges required for success in IBL projects [13]. The results of our present analysis suggest that some of these factors may have become further entrenched by pandemic-related learning disruptions. Learning loss created by the pandemic widened gaps in educational inequities and learning opportunity for students facing external challenges related to socioeconomic status [17], [18], [19].

Quantitative evidence of reduced post-pandemic classroom engagement in a more resource-constrained school participating in *Discovery* is now presented in this study (**Figure 1E**). A significant difference in classroom absences (between schools) had not been previously observed, although student attendance in the *Discovery* program from all schools aligns with previous, pre-pandemic program outcomes [13]. This contrast in engagement between *Discovery* and the classroom confirms the qualitative observations made in a recent post-pandemic program evaluation [8]. Enhanced engagement in the post-pandemic *Discovery* program noted by partner teachers has been attributed to providing students with a novel learning environment in modern university teaching laboratories, while closely interacting with graduate student mentors in this setting [8]. Several recent studies on post-pandemic learning outline increasing rates of chronic absenteeism in students, particularly for students from marginalized or socioeconomically disadvantaged backgrounds [16], [19], [20], [21]. Given that further analysis of classroom attendance has not been performed in previous program evaluations, we undertook a more detailed analysis where the context of classroom attendance is considered.

3.2 Identification of subsets of interest within the Spring 2025 student cohort

The EE subset of students from Spring 2025 are identified visually in **Figure 3A**, where EE students clearly fall above the dashed line representing one SD above the theoretical 1:1 line. The slope of the regression lines for EE (blue) and non-EE (gray) students were significantly different ($p = 0.0029$), confirming these lines are indeed distinct from each other; the slope of the linear regression for EE students is 0.1783, whereas the slope of the linear regression for non-EE students is 0.6959. The information regarding the schools from which EE students were enrolled is presented here, along with the percentage of EE students from each school cohort (**Figure 3B**). Schools A and B had 74% and 48% of students from their school fall within the EE subset *respectively*, whereas only 3% of students from School C were considered to meaningfully outperform their regular course performance during program activity. EE students obtained lower course grades than non-EE students (**Figure 3C**), however a significant difference in *Discovery* grades between EE and non-EE students was also observed (**Figure 3D**).



School	Number of EE students	Percentage of EE students within school cohort (%)
A	14	**73.68**
B	15	**48.39**
C	1	**3.13**
Total	30	**36.59**

School	Number of chronically absent (CA) students	Percentage of CA students within school cohort (%)
A	9	**47.37**
B	19	**61.29**
C	7	**21.88**

Figure 3. Identification of student subsets within the Spring 2025 cohort, including exceeds expectations (EE) and chronically absent (CA) groups. (A) Plot of *Discovery* grade versus course grade outlines the EE student subset, defined as students who obtain a *Discovery* grade one standard deviation higher (15.71%) than their course grade. (B) Information on EE students by school. Comparison of course (C) and *Discovery* (D) grades between EE and non-EE students in the Spring 2025 cohort. Comparison of course (E) and *Discovery* (F) grades between chronically absent (CA, 10% or more of missed class days) and non-chronically absent (non-CA, less than 10% of missed class days) students. (G) Information on chronically absent students by school. P-values reflect non-parametric Mann-Whitney U-tests between student subsets. Significance was determined if $p < 0.05$ in all comparisons.

Based on classroom attendance, 35 students (of n = 82 in total) within the aggregate Spring 2025 cohort data were identified as chronically absent (CA) from their class. Contrary to our expectations, no significant differences were observed between CA and non-CA groups in either course or *Discovery* grades (**Figure 3E, 3F**). **Figure 3G** presents the percentage of students from each school who were categorized as CA. Aligning with our comparisons of absences between schools, Schools A and B had higher proportions of CA students within their cohorts than School C.

Previous studies of *Discovery* program outcomes prior to the pandemic indicated that 37.0% of participating students fell into the EE subset [10]. Within the post-pandemic cohort, a similar number of students fall within the EE subset (36.6%; n = 30). We further identified that almost all EE students represent Schools A and B (n = 29 of n = 30 in total), and that a large percentage of students from Schools A and B within their respective school cohorts excelled in *Discovery* this semester. With the emerging prevalence of chronic absenteeism in post-pandemic classrooms, percentages of CA students in each school cohort were measured. This student subset is of particular interest to the current study, as evidence suggests rising levels of chronic absenteeism and associated learning loss in the years since the pandemic [15], [16], [19], [20], [21]. Of note, students from Schools A and B also comprised most of the CA-student subset in addition to the EE subset, compared to the School C cohort. These trends in classroom absences align well with studies outlining disparate challenges in post-pandemic learning engagement in schools within varying socioeconomic regions [19], [20], [21]. Nevertheless, these data suggest that *Discovery* is an effective program for engaging CA students and, importantly, that the academic performance of this cohort of students is enhanced by the program framework. These effects are further contrasted by the quantitative performance metrics from School C where, despite higher classroom engagement being observed, significantly fewer students excelled academically in *Discovery*. These data suggest that *Discovery* has a greater pedagogical impact on students from Schools A and B, and further reflects differences in access to STEM enrichment opportunities and learning resources relative to School C. Based on the quantitative data on EE and CA student subsets, *Discovery* presents as a highly effective learning model to draw engagement from students who may have faced external challenges to learning but have developed the grit, or internal resources, that shape students' drive to learn and excel academically when engaged in an open-ended, IBL environment.

While the data shown here have interesting implications for the *Discovery* program in the post-pandemic landscape, these data reflect only one semester of programming. Data collected in future semesters from multiple partner schools will be analyzed and included in our study of post-pandemic program outcomes to determine whether the trends observed in EE and CA student subsets remain consistent and continue to align with previous program outcomes. Intriguing results from this portion of our quantitative analysis are the trends shown in **Figure 3E** and **Figure 3F** that show no difference in grades between CA and non-CA students in both course and *Discovery* components. We found this counterintuitive, considering that chronic absenteeism is generally assumed to lead to diminished academic outcomes for students [15]. We considered that other variables related to pandemic-related learning disruptions, whether quantitative or qualitative by nature, may be at play regarding student performance post-pandemic. Therefore, an evaluation of data collected from pre-pandemic semesters is warranted to better understand the evolution of trends in student performance and perspectives on the *Discovery* program that may have changed.

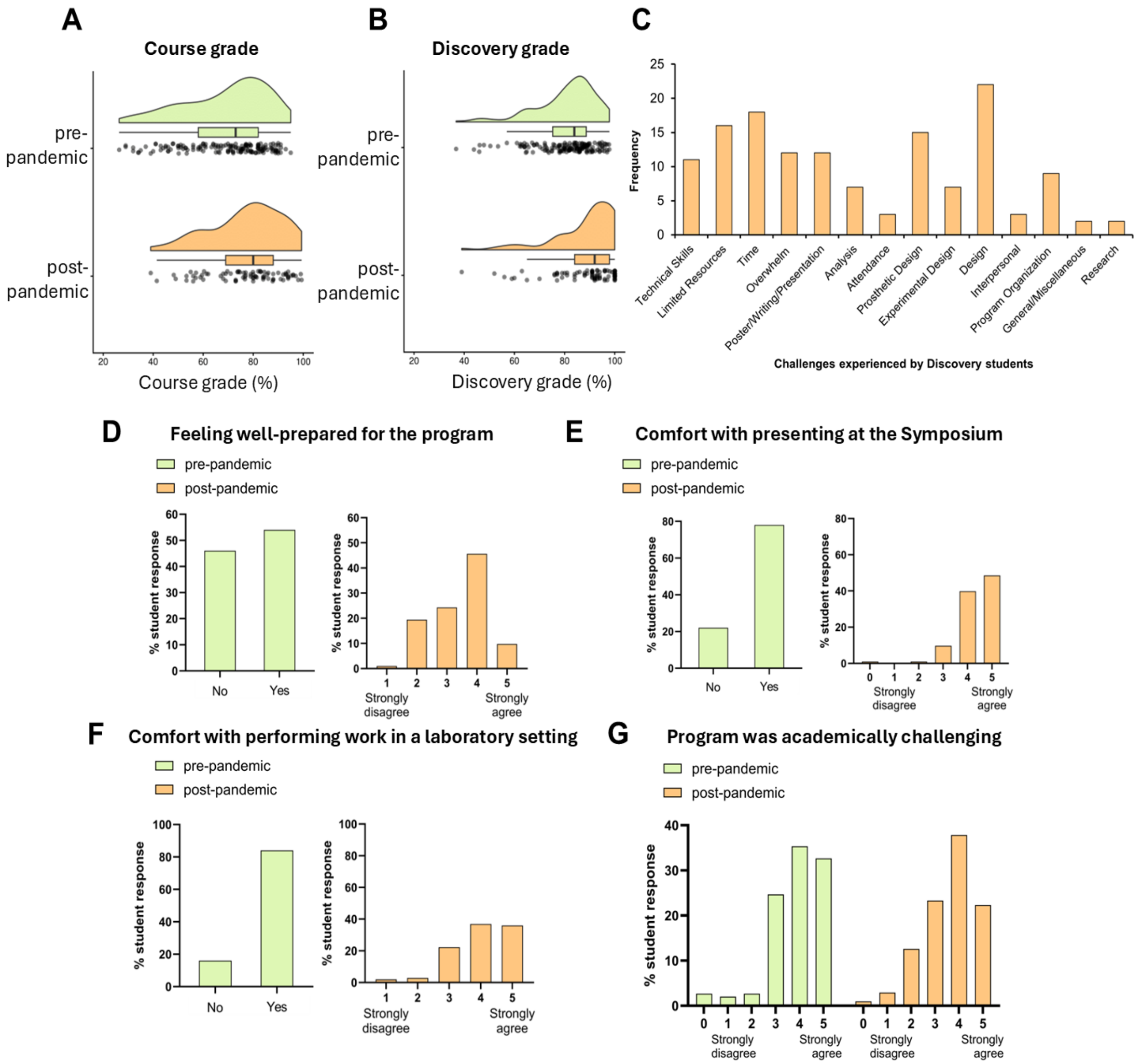


Figure 4. Evolving trends in student performance metrics and student opinion survey results regarding *Discovery* from pre-pandemic and post-pandemic semesters of programming. Raincloud plots for enhanced visualization of course (A) and *Discovery* (B) grade distributions. The raincloud plots permit a comprehensive visualization of grade data by providing raw data points (scatter), summary statistics (box plot), and probability densities (cloud). (C) Identification of the most difficult challenges experienced by students in the *Discovery* program in Spring 2025. Student survey responses from pre-pandemic and post-pandemic semesters regarding preparedness for *Discovery* (D), comfort with presenting a poster at the Symposium (E), performing work in a lab setting (F), and perceived academic challenge presented by the *Discovery* program (G). Pre-pandemic survey responses required a Yes/No answer by students, whereas post-pandemic survey responses were ranked by a 5-point Likert scale. Answers of ‘0’ in various prompts with Likert scale rankings indicate an answer of ‘Not Applicable’ (‘N/A’).

3.3 Evolving trends in student performance data and perspectives on the *Discovery* experience post-pandemic

With the overall study objective of understanding how the program has evolved following the post-pandemic return to in-person learning spaces, we sought to evaluate how student performance and attitudes towards *Discovery* participation have changed. It is important to note that no statistical comparisons to data collected from pre-pandemic semesters are made in this paper due to a myriad of changes in partner schools, teachers, school grading policies regarding the assessment of student deliverables, and to the *Discovery* program itself over a period of several years. However, data from pre-pandemic semesters are provided for context, as this information allows us to better understand the findings from analysis of Spring 2025 cohort, and provide richer context to the interpretation of these new results.

Aggregate grades from pre-pandemic as well as the Spring 2025 semester are presented in the form of raincloud plots. Notably, both median course and *Discovery* grades from the Spring 2025 cohort were higher than those obtained in pre-pandemic semesters. Aggregate pre-pandemic and post-pandemic median course grades were 73.0% and 79.9% *respectively* (**Figure 4A**), and pre-pandemic and post-pandemic *Discovery* grades were 83.9% and 92.0%, *respectively* (**Figure 4B**).

The elevated median post-pandemic course and *Discovery* grades may be indicative of a broader trend of grade inflation, which is now a demonstrated post-pandemic phenomenon [22]. There was a 6.9% differential in the median course grade and an 8.1% differential in the median *Discovery* grade between pre-pandemic and post-pandemic semesters. Within our program, grade inflation is further highlighted by our recent evaluation, where multiple teachers expressed that students demonstrated knowledge gaps on the content covered in science courses [8]. Given this context, the increase in post-pandemic grades appear counterintuitive. Nonetheless, the observed trends between course and *Discovery* grades remain similar to those observed in pre-pandemic semesters in that student academic performance is enhanced in *Discovery*.

Qualitative student survey responses were subsequently analyzed (**Figures 4C-4G**). Coded categories for responses to "*What did you find to be the most difficult aspect of the Discovery project?*" are presented in Figure 4C). A range of responses included "*technical skills*", "*(limited) time*", "*overwhelm*", "*analysis*", and "*design*", amongst other difficulties. Student responses regarding program preparation, comfort with program activities, and sense of academic challenge are similar in both pre- and post-pandemic semesters (**Figures 4D-4G**). Fifty-six percent of students felt prepared to participate in the *Discovery* program post-pandemic (answers of 4 or 5), which is similar to the 54% of students who felt prepared for *Discovery* in pre-pandemic semesters (**Figure 4D**). Most students (88%) agreed that they felt comfortable with presenting their *Discovery* projects during the Symposium, an increase from the 78% of students during pre-pandemic program offerings (**Figure 4E**). When considering the development of technical skills, 73% of students from the post-pandemic cohort indicated that they felt more comfortable with the idea of doing lab work in a post-secondary setting, which is a decrease from the 84% of students who positively indicated comfort with working in a lab in pre-pandemic semesters (**Figure 4F**). Finally, 60% of students from Spring 2025 perceived that the program provided them with an academic challenge (answers of 4 or 5 on the Likert Scale), compared to the 68% of students who indicated an academic challenge in the program pre-pandemic (**Figure 4G**). Although post-pandemic close-ended survey results indicated that, collectively, students carried generally positive attitudes to key program events, developed technical skills (related to their *Discovery* project), and perceived a challenge from program participation, some contrasts exist in relation to pre-pandemic survey outcomes. Namely, post-pandemic surveys indicated students did not feel as comfortable with laboratory work and perceived the program to provide a lower academic challenge relative to pre-pandemic cohorts, yet students felt more comfortable with presenting their work at the Symposium. This could be attributed to differences in student attitudes between partner schools as aggregate post-pandemic data are presented here; further data on student perspectives by school cohorts in post-pandemic offerings will be collected and discerned before determining whether changes to program delivery are required in future *Discovery* offerings.

An interesting aspect of the coded survey results in **Figure 4C** is that there was no singular challenge or most difficult aspect of the program identified by students in the aggregate post-pandemic cohort. One interpretation of having such a varied set of issues is that students were presented with the opportunity to genuinely engage in the *Discovery* project, and were therefore subsequently challenged by areas they may have been weaker in. Because *Discovery* offers different IBL projects in each discipline (biology, chemistry, physics) where different challenges may be encountered by students, further examination of discipline-specific student perceptions will be assessed using data collected over multiple semesters of programming. More broadly, the identification of various individual challenges could relate to students' Funds of Knowledge [23]. Funds of Knowledge is a framework that describes how enabling students to draw on their individual skillsets and lived experiences within the classroom allows for enhanced engagement and student learning opportunities [23], [24]. In an IBL setting where learning is student-centered, it is more likely that students themselves are required to draw on their own individual or collective skills (within their *Discovery* groups) to support their learning. While the open-ended, inquiry-based nature of the program provides an accessible way for students to draw on unique strengths through Funds of Knowledge, this same learning environment also enables students to identify and perhaps acknowledge the individual challenges they faced in the program. With the issues associated with the transition back to in-person spaces and post-pandemic learning [25], the *Discovery* program could serve as an equitable platform for transitioning into this new educational landscape by providing an open-ended learning environment where the most pressing challenges can be identified for individual students.

3.4 Analysis of chronic classroom absenteeism on *Discovery* student performance

The rates of classroom chronic absenteeism in the pre-pandemic and post-pandemic datasets within their respective aggregate cohorts reveal a large increase (approximately 1.6 times higher) in the proportion of students chronically absent from school post-pandemic compared to pre-pandemic (**Figure 5A**). Notably, the percentage of CA students within the EE subset of both pre-pandemic and post-pandemic datasets revealed that the number of CA students who also excelled academically in the *Discovery* program dramatically contrasted the percentage of students who were also EE students in the pre-pandemic cohort (**Figure 5B**).

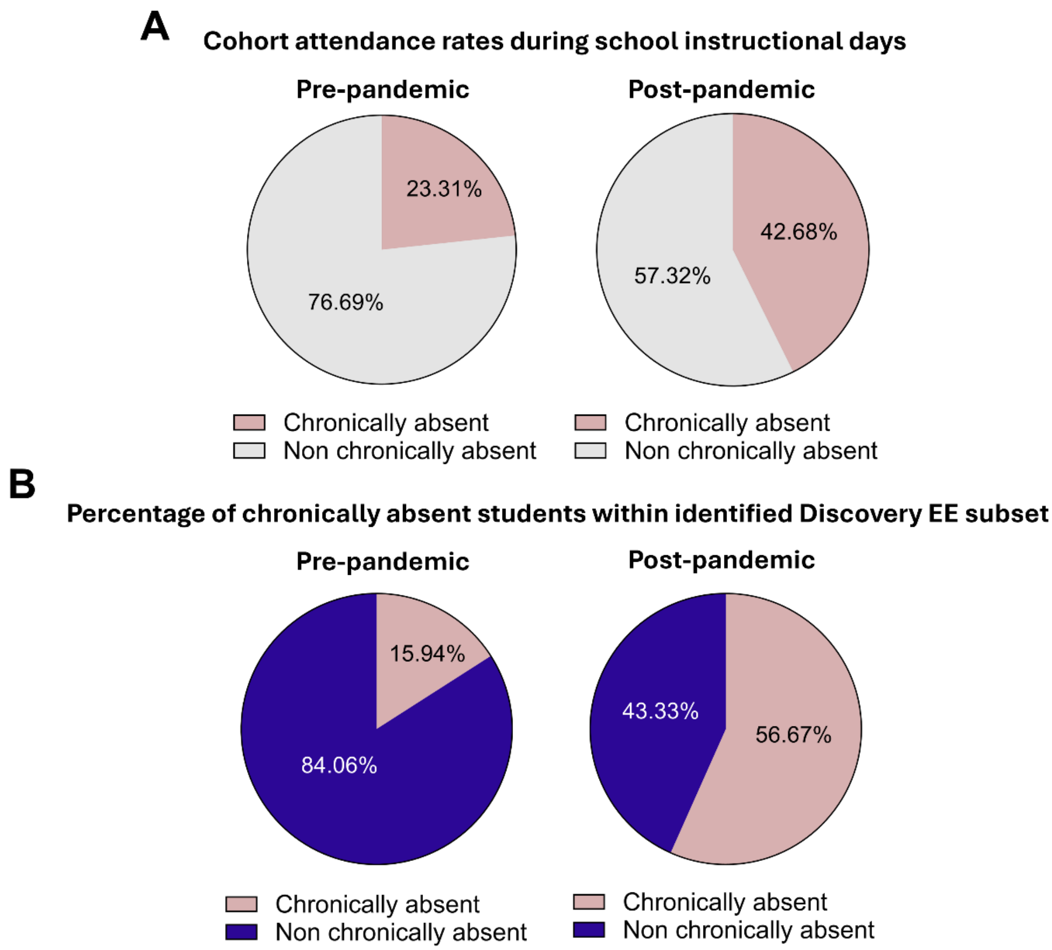


Figure 5. Analysis of chronic absenteeism in the classroom on *Discovery* program performance pre- and post-pandemic. (A) Proportion of chronically absent students in the classroom pre- and post-pandemic. (B) Proportion of chronically absent students within the identified EE subset pre- and post-pandemic.

Although a comparative estimate, the dramatic increase in classroom chronic absenteeism rates observed in these datasets align with the reported increases of pre-pandemic to post-pandemic chronic absenteeism in the literature [26], [27], [28], [29]. Some reports on post-pandemic attendance indicate that attendance rates are returning to pre-pandemic levels in some regions [30]; however, further data is required to substantiate and generalize these observations [29]. Intriguingly, in the pre-pandemic cohort, while course grades did not vary between CA and non-CA students, *Discovery* grades for the CA group were significantly lower than the those for the non-CA group (**Figure A1**). This finding contrasts the post-pandemic cohort, where no differences in the *Discovery* grade between CA and non-CA students were observed (**Figure 3E-G**).

While students participating in *Discovery* post-pandemic appeared to have benefitted from the program in terms of academic performance and engagement, we now observe a key difference in trends regarding the engagement of students in the EE subset, who are presumed to benefit the most from the program based on academic performance metrics. Prior to the pandemic, students who more regularly attended class appeared to benefit more from the *Discovery* program (**Figure A1**). This observation is reflected by differential academic performance in *Discovery* (median grades of 77.8% for CA versus 84.7% for non-CA), and by the relatively fewer CA students observed within the EE subset pre-pandemic (16% CA students in the EE subset versus 23% CA in the entire cohort). These data also suggest that chronic absenteeism negatively affected the grades that students obtained during pre-pandemic *Discovery* programming. Although the exact reasons for this observation are unknown, a simple explanation could be related to the requirements of successful IBL, in that a necessary background (that is acquired by attending class) is required for proper IBL engagement [9]. However, post-pandemic, CA students still perform similarly to students regularly attending class in both their course and the *Discovery* program (**Figure 3E-G**). Moreover, CA students are now being concentrated within the *Discovery* EE subset. While this observation demonstrates how *Discovery* and similar IBL programs could serve as an effective platform to reengage CA students, our findings could also be attributed to changes in school grading policies that would be required to adapt to be more accommodating of student absences in post-pandemic learning spaces.

Taken together, this trend suggests that *Discovery* continues to engage senior secondary students in a way that is distinct from the traditional classroom setting and its associated knowledge-based learning model. These findings confirm our recent thematic analysis and experiences in that the program serves as an effective tool in addressing emergent post-pandemic learning challenges by engaging CA students [8]. Considering that a large majority of students in the post-pandemic dataset attend all program visits, our findings suggest that *Discovery* rigorously engages CA students and provides a platform where they can excel in a similar manner to their classmates. The motivation of CA students to attend and excel in the *Discovery* program may be attributed to being immersed within a (more) stimulating or dynamic environment, where access to university facilities and opportunities for collaboration with peers and mentors support sustained engagement. Enhanced engagement of CA students is further highlighted with the non-trivial consideration that all students are responsible for arranging independent travel to campus, indicating the value that students place in the *Discovery* learning model [10]. Therefore, students likely perceive the opportunity cost of missing a *Discovery* campus visit to be much greater than missing a day of typical classroom activities. Another motivation behind why CA students may be engaging in *Discovery* is the consistent and tangible nature of their IBL project. Because students undertake the same *Discovery* project throughout the semester of programming, it is likely easier for students to return to if activities are missed, as the high-level content and motivating context behind the project remain similar. On the other hand, if CA students miss multiple days of class, making up for materials that span several different topics may prove overwhelming and likely perpetuates the negative feedback loop surrounding post-pandemic disengagement in the classroom [8], [15], [26]. Thus, *Discovery* projects enable teachers to ground scientific theory covered in class to a tangible application and provide a motivating context to return to learning by using the project as a case study. Ultimately, providing CA students an opportunity to excel academically in an IBL program such as *Discovery* enables the development of long-term learning habits and promotes self-efficacy in post-secondary STEM environments, thereby addressing the post-pandemic challenges surrounding engagement and perseverance.

The findings from this post-pandemic dataset could be attributed to a number of factors including grade inflation [22] and changes to the assessment methods and curricula of both course and *Discovery* deliverables. Additionally, while teachers have expressed that *Discovery* serves as a platform to reengage students and sustain long-term learning habits beyond the program [8], whether CA students who excel in *Discovery* continue engaging in (future) science courses after programming would need to be determined. Further study will seek to identify longer-term trends of student engagement or performance from schools from varying socioeconomic regions, in addition to more longitudinal outcomes on student engagement following participation in the program.

4. Conclusions

Herein, we present outcomes of the *Discovery* learning model through student performance, with the aim of evaluating how the role of the program and its impact have shifted in post-pandemic secondary science learning. Grade, survey, and attendance data were collected from three partner schools, each facing various degrees of external challenges to learning. Quantitative analysis of course and *Discovery* performance metrics revealed that overall, student performance continues to be enhanced in the *Discovery* program, consistent with pre-pandemic program outcomes. Analysis of both academic performance and engagement metrics by school revealed the differential impact of *Discovery* on students from different schools, demonstrating enhanced engagement of students with varying degrees of learning opportunity. Identification of subsets of interest revealed a significant proportion of students continue to excel in the *Discovery* program, despite a large number of the post-pandemic student cohort being chronically absent from the classroom. Post-pandemic student surveys revealed that student attitudes towards the program were generally positive and that the program enabled students to identify individual academic challenges during participation. Furthermore, analysis of chronic absenteeism in the classroom on *Discovery* program performance in the post-pandemic cohort demonstrated contrasting trends to pre-pandemic outcomes. A larger proportion of students who excelled academically in the program were also chronically absent from class, further underlining the impact of the program by both engaging students who have experienced pandemic-related learning loss, and providing a platform in which they can excel in this post-pandemic educational landscape.

References

[1] I. DeCoito and M. Estaiteyeh, 'Online teaching during the COVID-19 pandemic: exploring science/STEM teachers' curriculum and assessment practices in Canada', *Disciplinary and Interdisciplinary Science Education Research*, vol. 4, no. 1, p. 8, Dec. 2022.

[2] Pintaric Zorka Novak and Kravanja Zdravko, 'The Impact of the COVID-19 Pandemic in 2020 on the Quality of STEM Higher Education', *Chemical Engineering Transactions*, vol. 81, pp. 1315–1320, Aug. 2020.

[3] K. Gallagher-Mackay *et al.*, 'COVID-19 and Education Disruption in Ontario: Emerging Evidence on Impacts', Ontario COVID-19 Science Advisory Table, June 2021.

[4] C. Deák, B. Kumar, I. Szabó, G. Nagy, and S. Szentesi, 'Evolution of New Approaches in Pedagogy and STEM with Inquiry-Based Learning and Post-Pandemic Scenarios', Education Sciences, vol. 11, no. 7, p. 319, June 2021.

[5] E. R. Wester, L. L. Walsh, S. Arango-Caro, and K. L. Callis-Duehl, 'Student Engagement Declines in STEM Undergraduates during COVID-19–Driven Remote Learning', Journal of Microbiology & Biology Education, vol. 22, no. 1, p. ev22i1.2385, Apr. 2021.

[6] J. Whitley, M. H. Beauchamp, and C. Brown, 'The impact of COVID-19 on the learning and achievement of vulnerable Canadian children and youth', FACETS, vol. 6, pp. 1693–1713, Jan. 2021.

[7] A. M. Boelt, A. Kolmos, and J. E. Holgaard, 'Literature review of students' perceptions of generic competence development in problem-based learning in engineering education', European Journal of Engineering Education, vol. 47, no. 6, pp. 1399–1420, Nov. 2022.

[8] N. Ivanov et al., 'Re-evaluation of an immersive secondary school inquiry-based STEM program post pandemic: Understanding how to meet student needs after learning disruptions (Evaluation)', in 2025 ASEE Annual Conference & Exposition, 2025.

[9] J. Chen, A. Kolmos, and X. Du, 'Forms of implementation and challenges of PBL in engineering education: a review of literature', European Journal of Engineering Education, vol. 46, no. 1, pp. 90–115, Jan. 2021.

[10] L. Davenport Huyer et al., 'Enhancing senior high school student engagement and academic performance using an inclusive and scalable inquiry-based program', npj Science of Learning, vol. 5, no. 1, p. 17, Dec. 2020.

[11] L. Davenport Huyer et al., 'IBBME Discovery: Biomedical Engineering-based Iterative Learning in a High School STEM Curriculum (Evaluation)', in 2018 ASEE Annual Conference & Exposition, 2018.

[12] F. Avikpe et al., ‘A Structured Approach to Developing Open-Ended Scientific Research Projects for Secondary Students in a Graduate Student-Led Education Program’, Proceedings of the Canadian Engineering Education Association (CEEA), July 2025.

[13] N. Callaghan et al., ‘Discovery: Differential Student Impact is Evident Within an Inquiry-focused Secondary/Post-secondary Collaborative STEM Program’, in 2020 ASEE Virtual Annual Conference Content Access, 2020.

[14] “The 2023 Learning Opportunities Index,” [Local School District] Board, [Location]. Accessed Jan. 17, 2026. [Online].

[15] M.A. Rogers, J. Whitley, D. Smith, N. McBrearty, L. Gowans. ‘Impact of COVID-19 on School Absenteeism among [Country] Children and Youth’ Journal of the [Country] Academy of Child and Adolescent Psychiatry, vol. 34, no. 3, Dec. 2025.

[16] H. Harris, ‘Chronic student absenteeism’, 2019.

[17] A. Walters, ‘Inequities in access to education: Lessons from the COVID-19 pandemic’, *The Brown University Child and Adolescent Behavior Letter*, vol. 36, no. 8, pp. 8–8, Aug. 2020.

[18] J. A. Supovitz and O. Manghani, ‘The Role of Inequity in School Responses to the COVID-19 Pandemic’, *Peabody Journal of Education*, vol. 97, no. 3, pp. 257–273, May 2022.

[19] A. R. Golden, E. N. Srisarajivakul, A. J. Hasselle, R. A. Pfund, and J. Knox, ‘What was a gap is now a chasm: Remote schooling, the digital divide, and educational inequities resulting from the COVID-19 pandemic’, *Current Opinion in Psychology*, vol. 52, p. 101632, Aug. 2023.

[20] W. N. Evans, K. Muchnick, and O. Rosenlund, ‘Virtual Learning in Kindergarten Through Grade 12 During the COVID-19 Pandemic and Chronic Absenteeism’, *JAMA Network Open*, vol. 7, no. 8, p. e2429569, Aug. 2024.

[21] E. M. Sosu, S. Dare, C. Goodfellow, and M. Klein, ‘Socioeconomic status and school absenteeism: A systematic review and narrative synthesis’, *Review of Education*, vol. 9, no. 3, p. e3291, 2021.

[22] D. Goldhaber and M. Goodman Young, ‘Course grades as a signal of student achievement: Evidence of grade inflation before and after COVID-19’, *Journal of Policy Analysis and Management*, vol. 43, no. 4, pp. 1270–1282, 2024.

[23] L. C. Moll, C. Amanti, D. Neff, and N. Gonzalez, ‘Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms’, *Theory Into Practice*, vol. 31, no. 2, pp. 132–141, Mar. 1992.

[24] G. M. Rodriguez. “Power and agency in education: Exploring the pedagogical dimensions of Funds of Knowledge,” Rev. Res. Educ., vol. 37, no. 1, pp. 87-120, Mar. 2013, doi: 10.3102/0091732X12462686

[25] J. Guryan and J. Ludwig. “Overcoming pandemic-induced learning loss,” in Building a More Resilient US Economy, M. S. Kearney, J. Schardin, and L. Pardue, Eds. Washington DC. Aspen Institute, 2023.

[26] T. S. Dee, ‘Higher chronic absenteeism threatens academic recovery from the COVID-19 pandemic’, *Proceedings of the National Academy of Sciences*, vol. 121, no. 3, p. e2312249121, Jan. 2024.

[27] N. Malkus, ‘Long COVID for Public Schools: Chronic Absenteeism before and after the Pandemic’, American Enterprise Institute, Jan. 2024.

[28] Meyer, Robert H., ‘Social Emotional Learning, Student Attendance, and Chronic Absenteeism in Pre- and Post-Pandemic Periods’.

[29] C. Vidal, L. Hinson, and E. Bartolini, ‘School Absenteeism and the COVID-19 Pandemic: The Role of Pediatricians’, *Clinical Pediatrics*, vol. 63, no. 1, pp. 5–9, Jan. 2024.

[30] N. Malkus, ‘Lingering Absence in Public Schools: Tracking Post-Pandemic Chronic Absenteeism into 2024’, American Enterprise Institute, June 2025.

Author contributions

NEB, RC, NI, NS, NTN, and ZZ contributed equally to this work, and these authors are listed alphabetically. Correspondence can be directed to DMK.

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Appendix

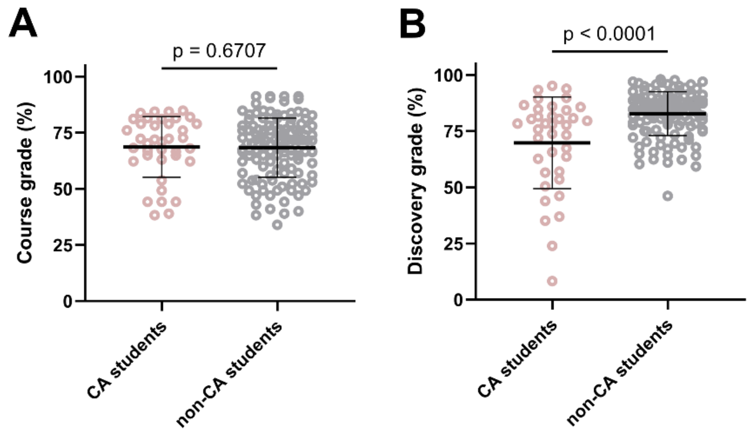

Figure A1. Analysis of CA students from pre-pandemic semesters of Discovery. Comparisons of pre-pandemic course (A) and Discovery (B) grades between students who are chronically absent during class days versus non chronically absent students. Post-pandemic comparisons of course and Discovery grades for CA versus non-CA students are located in **Figure 2**. P-values reflect non-parametric Mann-Whitney U-tests between student subsets. Significance was determined if $p < 0.05$ in all comparisons.