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Reinventing Secondary School through design: An investigation of a Polytechnic High School Model focused on industry/community-driven design projects

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Abstract

This study examines the impact of a polytechnic high school model designed in collaboration with a research-intensive university and industry/community partners. Aimed at urban settings and focused on minoritized youth, this model replaces traditional subject-specific classes with industry-driven design project cycles. As design-based integrated STEM learning gains global traction, this research offers valuable insights. Pre/post surveys administered to seniors and teachers, along with follow-up surveys and focus groups with alumni during their first semester of college. This study explores the model's effect on college and career readiness, teachers' perceptions of its effectiveness, and challenges encountered in implementing design-based instruction. Through an exploration of the model's successes and challenges, this study provides actionable recommendations for polytechnic models, contributing to the broader discourse on design-based STEM instruction.

Keywords

Design-based learning, Secondary School Transformation, Integrated STEM Education

Introduction

Calls for a reformation of secondary education in the United States persist among higher education institutions and employers, aiming to align learning with the evolving demands of our society (Indiana Commission for Higher Education, 2020). Growing concern that high school graduates lack adequate preparation for college and are out of sync with anticipated workforce requirements. The traditional high school paradigm, characterized by fixed schedules, rote memorization, teacher-centered instruction, and standardized curricula, seen as ill-suited for success in contemporary society and the professional arena (Casner-Lotto & Barrington, 2006). This conventional "factory model of education," described by Serafini (2002) as treating students as products and structuring education, accordingly, not originally designed to foster critical thinking, creativity, problem-solving, or other 21st-century skills (Wheatley, 2015). Employers echo these concerns, perceiving a deficit in crucial workplace competencies among students, including communication, creativity, and critical thinking (Casner-Lotto & Barrington, 2006).

Secondary education provides students with a universal foundation of learning through curricula designed to help every student achieve similar levels of understanding or designated learning outcomes (Leland & Kasten, 2001). To achieve these learning outcomes, schools have established disciplinary silos for teaching subjects like mathematics, science, history, and

language arts. This siloed approach has been the dominant way that schools function and curricula have been structured. However, this siloing of disciplines can deprive students of opportunities to make valuable and authentic connections between subjects while in school (Kirwan et al., 2022). According to Kirwan et al. (2022), the siloed educational system can cause inefficiencies in developing well-rounded and thorough instructional resources and curricula, which can directly impact student learning. This situation can be particularly challenging for schools serving diverse student populations, where traditional educational approaches may not align effectively with local cultures and communities (Paris, 2012).

Today, the challenges our world faces have become more complex, and education can be the key to developing the necessary skills students will need for their careers and lives to work toward these complex problems in the future (Hodge & Lear, 2011). For example, the 2020 STEM education visioning report published by the National Science Foundation highlights the goal of creating transformative learning experiences that involve innovative ways to work across disciplinary silos to solve big challenges. This approach is argued to help ensure that high school graduates are adequately prepared for college/careers and are not “out of sync” with anticipated workforce requirements. It is believed that these transformative learning experiences can prepare students by enhancing their “21st-century skills” (Partnership for 21st Century Skills, 2013) such as creativity, communication, and collaboration abilities.

In alignment with these demands, there has been an increased emphasis on integrated STEM (science, technology, engineering, and mathematics) programming and initiatives in secondary schools (Yuxin & Williams, 2013). Design-based learning has emerged as a common pedagogical strategy to integrate the STEM disciplines in schools (Wells & Van de Velde, 2020). This strategy involves planning instruction in a way that allows learners to activate their prior knowledge and construct new knowledge through the practice of designing solutions to problems (Strimel, 2023). However, creating authentic learning experiences that involve innovative ways to work across disciplinary silos in the resolution of meaningful and relevant problems is an organizational challenge, as schools are not typically structured in a way that allows this to occur (Strimel, 2023).

One innovative response to these challenges is the development of the polytechnic high school model, which was created to challenge the traditional siloed, factory model of education. The polytechnic school model, implemented as urban STEM-focused charter schools, has been established through collaborations involving state universities, local governments, industry leaders, and community stakeholders. The polytechnic high school model emphasizes personalized, experiential learning within an integrated STEM framework, encouraging students to pursue their passions across academic disciplines through real-world projects and design challenges conducted in partnership with industry. This approach, labelled as "polytechnic," integrates technological concepts with relevant industry contexts. Developed in collaboration with their university partner, this school model prioritizes instructional practices that foster innovation, collaboration, and creativity among diverse student groups, aiming to address real-world problems with novel solutions.

With the implementation of this new school model, there was an opportunity to learn more about attempts to "reinvent secondary schooling” through a model centered around industry/community-driven design projects. Therefore, this study delves into the innovative

polytechnic school model, a partnership between a public research-intensive university and various industry and community collaborators. Here, design project cycles, created in conjunction with local partners, take center stage in instruction, replacing traditionally siloed, subject-specific classes. Given the global emphasis on integrated STEM learning through design projects (Strimel, 2023; Wells & Van de Velde, 2020; Yuxin & Williams, 2013), exploring this polytechnic school model and its design-based approach offers valuable insights toward enhancing STEM education opportunities and design-based teaching.

Table 1. Skills Emphasized in Polytechnic Education and Training (Mercer & Ponticell, 2012).

• Focus Areas
• Emphasis on science, technology, and professional and technical programs, complemented by arts, humanities, and social sciences • Smaller class sizes • Integrated curriculum, practical and theoretical exercises throughout programs • Hands-on, project- and team-based learning environment • Applied, collaborative research and technology transfer • Cross-disciplinary and co-curricular experiences, internships, and service learning • Social responsibility • Civic engagement • Innovation and entrepreneurship • Leadership in scientific, economic and community development • Adaptation/responsiveness to needs/demands of business, industry and society

Background of Polytechnic Models

Various forms of relationships between schools, universities, and communities abound today, serving diverse purposes. Collaborations among educational institutions spanning elementary, secondary, and higher education, and with communities, have long been advocated. For the model examined in this study to qualify as a school-university collaboration, collaborative efforts must involve both institutions—the polytechnic model and the university—rather than being driven solely by individual teachers or staff members at each institution. Polytechnic schools, also referred to as practical arts institutions by Brint et al. (2005), are characterized as offering a "practical/occupational" educational approach (Mercer & Ponticell, 2012). Mercer and Ponticell (2012) outline a polytechnic educational model that highlights: a campus environment fostering interdisciplinary collaboration, utilization of innovative instructional technologies, experiential and applied problem-based learning, emphasis on applied research, convergence of disciplinary approaches, and active engagement with local and global communities, aiming to demonstrate sustainable educational and economic progress. Moreover, polytechnic educational models are noted for their emphasis on integrated STEM education and pedagogical approaches centered around student-centered, experiential learning. The goal is to equip individuals for knowledge-based economies by bridging education with industry (Mercer & Ponticell, 2012). Ultimately, polytechnics share common missions that blend theory and practice to address real-world challenges and cultivate skills essential for the contemporary workplace (Mercer & Ponticell, 2012). Table 1 illustrates some of the skills highlighted in polytechnic education (Mercer & Ponticell, 2012).

Study Context: Polytechnic High School and University Collaboration

Overview

A flagship research-intensive university, in collaboration with the largest city in the state, has established a distinctive polytechnic school-university collaborative model. The school model in this study comprises a network of STEM-focused public charter high schools (grades 9-12, ages 13-18) designed to equip students with the skills required for success in college and careers within a constantly evolving workforce. Introduced in August 2017, the school model was established with the following objectives: 1) to prepare underrepresented minority students for STEM careers, 2) to foster academic excellence and college readiness through experiential learning, and 3) to offer a comprehensive and equitable education to all students, irrespective of their academic achievements or socioeconomic status. By 2021, the model had expanded to encompass three campuses situated in urban areas throughout the state. Within this model, excellence and readiness are cultivated through a STEM-focused, project-based, experiential learning approach. Students engage in solving real-world problems through design challenges partnered with industry, embodying the essence of a "polytechnic high school," which emphasizes the application of technological concepts alongside arts and sciences within relevant industry contexts. Furthermore, the teachers at the polytechnic schools, referred to as coaches, collaborate with industry/community representatives to create design cycles that align with academic standards and provide students with rigorous STEM activities that reflect real-world problems or opportunities.

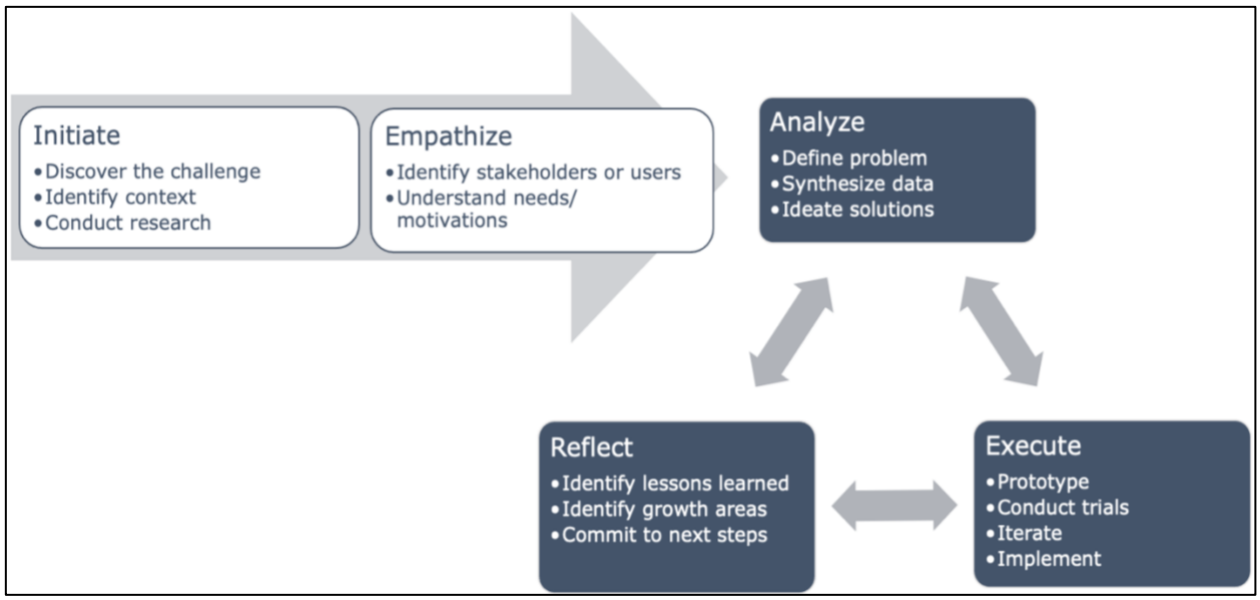

Figure 1. The Polytechnic High School Model Design Process.

Utilizing the Engineering Design Process in Industry-Partnered Projects

Developed in collaboration with the university's technology-focused academic unit, the model fosters innovation, collaboration, and creativity among diverse interdisciplinary groups, striving to devise novel solutions to real problems through their engineering design process (see Figure 1). What sets this school model apart from traditional educational models is its industry-driven and personalized approach to learning. Rather than delivering courses in conventional subjects such as mathematics, science, and language arts, students acquire desired concepts and skills through industry-partnered design challenges and student-centered passion projects. To facilitate this, the school operates on 6-week project cycles (see Figure 2), each commencing

with a new design challenge partnered with an industry entity and concluding with an idea pitch to that partner. These design challenges integrate state academic standards, prompting students to tackle challenging questions, develop prototypes, and craft business models. At the end of each cycle, student teams pitch their solutions to a variety of school, community, and industry stakeholders. This design-based learning approach encourages students to solve authentic, complex, and multifaceted problems.

Figure 2. Example Design-Cycles

Polytechnic Model Day-by-day

In contrast to the common eight, subject-specific class periods (Canady & Rettig, 1995) or four-by-four class block (Jenkins et al., 2002) daily schedules found in many schools, students in the polytechnic model engage in designated “design time” and learning “dojos” throughout the week. Design time is specifically set aside for students to work on the industry-driven design challenge for the current design cycle. Dojos, in this polytechnic model, are intimate group sessions targeting specific subjects, where students can participate voluntarily or by invitation. During dojos, students collaborate with teachers to delve deeper into subjects or address issues related to the design cycle. Outside of these sessions, students have Personal Learning Time (PLT) to independently navigate modules within an online learning platform. The PLT is established to help students demonstrate specific competencies desired by the school as well as state standardized assessments. The idea is that this PLT allows students to advance at their appropriate pace through the desired content and competencies rather than moving along at the same speed as a cohort of students based on their age. Most of the PLT incorporates an online learning platform component, constituting up to 50% of the students' progress in

learning, with teachers offering support as needed during independent study periods. Another distinctive feature of the polytechnic model is its emphasis on passion projects, wherein students select projects to work on that are either designed by teachers or proposed by the students themselves. These projects provide another way for students to demonstrate mastery of the school's desired competencies, enhance their autonomy in learning, and connect with teachers. All these approaches involve integrating various innovative educational strategies within the school model. Lastly, it is important to note that students who graduate from the model with a specific grade point average and a specific score on a college entrance exam are granted direct admission to the collaborating university.

Research Questions

The polytechnic high school model is positioned to provide an innovative approach to education that addresses the demands for 21st-century skills and achieves integrated STEM learning through a non-siloed approach centered on industry/community-driven design cycles. An exploratory study on how this school model was implemented and its potential influence on student learning provides an opportunity to enhance our understanding of school-wide transformation efforts emphasizing integrated STEM learning through design-based teaching. Consequently, the following research questions were developed to guide this study:

- What are the influences of a polytechnic high school model, centered on industry/community-driven design challenges, on student learning (i.e., 21st-century skills, sense of belonging, and college/career intent) as perceived by the students and teachers?
- What are the challenges and successes of a polytechnic high school model, centered on industry/community-driven design challenges, from the perspectives of teachers, students, and alumni?

Methods

Study Design

To address research question 1, data from the 2020-2021 school year were sourced from a beginning-of-year survey at one school location and pre/post-surveys administered to teachers and the first set of alumni, both before and after their first semester at the collaborating university. Surveys included Likert-scale items and open-ended questions to assess 21st-century skills (Creativity, Communication, Collaboration), sense of belonging, and college/career intent. Likert-scale items were adapted from Kelley et al.'s (2019) 21st Century Skills Survey and Anderson-Butcher and Conroy's (2002) Belonging Scale, which were validated for reliability. Open-ended responses provided a holistic view of student and teacher perceptions.

To address research question 2, focus group interviews were conducted with alumni who attended the collaborating university after their first semester. The interviews, along with teacher survey responses on the polytechnic model's challenges and successes, were recorded, transcribed, and analyzed using thematic coding (Saldaña, 2021) to extract key themes on the successes and challenges of the school model.

Survey Instruments

The teacher and student surveys consisted of 24 Likert scale items across four subscales: Creativity, Communication, Collaboration, and Belonging. The 21st-century skills (Creativity,

Communication, Collaboration) were measured using items adapted from Kelley et al.'s (2019) 21st Century Skills Survey, while the Belonging subscale used five four-point items from Anderson-Butcher and Conroy's (2002) Belonging Scale. These items help assess program impact and predict attendance patterns. Anderson-Butcher and Conroy's scale, validated with participants aged 9 to 18, demonstrated high reliability (α = .96) and was deemed appropriate for the study's alumni, despite their older age.

Table 2. Alumni Open-ended Response Questions

Pre-Survey	Post-Survey
What did you like most about your past school year at your high school?	What did you like most about the past semester at the collaborating university? Why?
How would you describe your high school to other students? What would you feel the need to tell them?	On a scale of 1-10, how well were you prepared for the learning environment here (collaborating university)? Why?
Reflecting on your experiences, what could make a student a good fit for your high school?	What were the biggest challenges with the learning environment here (collaborating university)? Why?
From attending your high school, what do you think makes you different/standout from students who attended a traditional high school?	Looking back, what would you change about your high school model?
What are you most worried about for this academic year at the collaborating university?	After being here for a semester, how did the collaborating university live up to your expectations? Why?
What are you most excited about this academic year at the collaborating university?	What do you wish you had known before making your decision to come here (collaborating university)?
	Now that you have completed a semester of higher education, what are your educational and career plans?

The 19 items measuring 21st-century skills remained consistent across all surveys, with minor adjustments to prompts based on participant groups (students, alumni, or teachers). For instance, alumni pre-surveys began with "Based on my high school experience, I am confident in my ability to..." while other surveys used "I am confident in my ability to...". Teacher surveys adapted the prompt to reflect their students' abilities. The surveys also included open-ended and multiple-choice questions to capture perceptions of the polytechnic model and, for alumni, their experiences at the collaborating university. The open-ended response questions from the alumni pre- and post-surveys are presented in Table 2.

As for the teachers' open response questions, there were two in the pre-survey asking the teachers what they are most worried about for the upcoming school year and what they were most excited about for the upcoming school year. In the post-survey administered to teachers, there were six open response questions which can be seen in Table 3.

Table 3. Teacher Open-ended response questions

Pre-Survey	Post-Survey
What are you most worried	What did you like most about this school year? How would you describe this school to other teachers? What would you feel the need to tell them?

about for this school year?	Reflecting on your experience this school year, what new challenges did you encounter?
What are you most excited for this school year?	Reflecting on your experience, what could make a student a good fit for this school?
	From working at this school, what do you think makes you different/standout from individuals who teach at a traditional school?
	From working at this school, what do you think makes you different/standout from individuals who teach at a traditional school?

Alumni Focus Group Protocol

This study's focus group design followed established guidelines from the literature. Hays and Singh (2011) emphasize the importance of selecting participants with shared experiences and equal influence over the discussion. Accordingly, all participants were freshmen who attended the innovative school model. Focus groups are typically recommended to have six to twelve participants, one to two moderators, and three to eight open-ended questions, with flexibility for follow-up queries (Hays & Singh, 2011). In line with these recommendations, our focus group included six participants, one facilitator, and five pre-determined open-ended questions:

1. How well were you prepared for the learning environment here?
2. What were the biggest challenges with this learning environment?
3. What surprised you after being here for a semester?
4. What supports would be helpful for the [high school] alum after arriving here?
5. Looking back, what would you change about the [high school] model? About the [collaborating university] model?

Findings

Research Question 1

Research question one explored the impact of a polytechnic high school model on student learning outcomes, specifically 21st-century skills, sense of belonging, and college/career intent, as perceived by students and teachers. Data from one senior class and alumni were analyzed using descriptive statistics and thematic coding, and the findings are presented by participant group (High School Seniors and Alumni). Twelve seniors (71% of the class) from one polytechnic school responded to a survey at the start of the 2021-22 school year. When asked about their post-graduation plans, seven intended to attend a 4-year college (six at the collaborating university), two planned to work full-time, and three were undecided. Figure 9 presents these responses.

The senior survey included Likert scale items across four subscales: Collaboration, Communication, Creativity (collectively 21st-century skills), and Belonging. Seniors reported the highest confidence in teamwork and decision-making but felt least confident in presenting information clearly. In terms of Belonging, all seniors felt supported by their school, though three expressed concerns about commitment, acceptance, and comfort. Two open-ended questions highlighted a mix of excitement about completing high school and concerns about graduation, with themes identified through thematic coding (Saldaña, 2021). Ten alumni (about 26% of the alumni class attending the collaborating university) completed the pre-survey before the 2021-22 academic year. Their responses are presented in Table 5.

Table 4. High School Senior Survey Responses (N = 12).

Number of Participants Selecting each Likert-Scale Response						
	Question: "I can…"	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Collaboration	Q1. be polite and kind to teammates	1	0	0	3	8
	Q2. acknowledge and respect other perspectives	1	0	1	5	5
	Q3. follow rules for team meetings	1	0	1	4	4
	Q4. make sure all team members' ideas are equally valued	1	1	1	3	6
	Q5. offer assistance to others in their work when needed	1	2	0	6	3
	Q6. improve my own work when given feedback	1	0	1	4	6
	Q7. use appropriate body language when presenting	1	0	3	3	5
	Q8. come physically and mentally prepared each day	1	2	3	3	3
	Q9. follow rules for team decision-making	1	0	0	4	7
Communication	Q10. use time, and run meetings, efficiently	1	1	2	6	2
	Q11. organize information well	1	0	2	6	3
	Q12. track our team's progress toward goals and deadlines	1	1	3	5	2
	Q13. complete tasks without having to be reminded	1	1	3	5	2
	Q14. present all information clearly, concisely, and logically	1	0	4	4	3
Creativity/ Innovation	Q15. Understand how knowledge or insights might transfer to other situations or contexts	1	1	1	4	5
	Q16. Find sources of information and inspiration when others do not	2	0	1	3	6
	Q17. Help the team solve problems and manage conflicts	1	1	2	5	3
	Q18. Adapt a communication style appropriate for the purpose, task, or audience	1	1	2	5	3
	Q19. Elaborate and improve on ideas	1	0	1	7	3
Belonging	Question	NO!	No	Yes	YES!	
	Q20. I feel comfortable at this school.	0	2	7	3	
	Q21. I am a part of this school.	0	1	8	3	
	Q22. I am committed to this school.	0	1	6	5	
	Q23. I am supported at this school.	0	0	7	5	
	Q24. I am accepted at this school.	0	1	5	6	

Participants reported the highest confidence in Collaboration skills but demonstrated varied confidence in Communication, particularly in presenting information clearly. While all felt supported at the collaborating university, some voiced concerns about commitment and comfort. Open-ended responses praised the school model for its flexibility in project choice and hybrid learning structure. Students recommended that success at the school requires dedication, independence, and adaptability. Although they anticipated challenges with workload and academic adjustments at the university, they expressed excitement about new learning opportunities and networking. Four alumni (about 10% of the class pursuing higher education at the collaborating university) completed the post-survey. Their responses are shown in Figure 11.

Table 5. Alumni Pre-Survey Responses (N = 10).

Number of Participants Selecting each Likert-Scale Response						
	Question: "I can…"	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Collaboration	Q1. be polite and kind to teammates	0	0	2	0	8
	Q2. acknowledge and respect other perspectives	0	0	1	1	8
	Q3. follow rules for team meetings	0	0	0	2	8
	Q4. make sure all team members' ideas are equally valued	0	0	0	4	6
	Q5. offer assistance to others in their work when needed	0	0	1	3	6
	Q6. improve my own work when given feedback	0	0	0	3	7
	Q7. use appropriate body language when presenting	1	0	0	3	6
	Q8. come physically and mentally prepared each day	1	2	1	2	4
	Q9. follow rules for team decision-making	0	0	1	3	6
Communication	Q10. use time, and run meetings, efficiently	0	1	0	4	5
	Q11. organize information well	0	1	1	4	4
	Q12. track our team's progress toward goals and deadlines	0	0	1	4	5
	Q13. complete tasks without having to be reminded	0	0	1	3	6
	Q14. present all information clearly, concisely, and logically	0	1	0	3	6
Creativity/ Innovation	Q15. Understand how knowledge or insights might transfer to other situations or contexts	0	0	1	2	7
	Q16. Find sources of information and inspiration when others do not	0	0	1	5	4
	Q17. Help the team solve problems and manage conflicts	0	1	1	1	7
	Q18. Adapt a communication style appropriate for the purpose, task, or audience	0	0	1	5	4
	Q19. Elaborate and improve on ideas	0	0	1	3	6
Belonging	Question	NO!	No	Yes		YES!
	Q20. I feel comfortable at this school.	0	0	5		5
	Q21. I am a part of this school.	0	1	4		5
	Q22. I am committed to this school.	0	1	4		5
	Q23. I am supported at this school.	0	1	2		7
	Q24. I am accepted at this school.	0	0	3		7

Participants expressed strong confidence in 21st-century skills, especially Communication, and felt a sense of belonging at the collaborating university. Open-ended responses highlighted positive experiences, such as the college atmosphere and networking opportunities, but also challenges like balancing workload. Suggestions for improving the high school model included better math instruction and returning to industry-based design cycles. Expectations of the university were mixed – students praised social experiences but criticized academic organization. Many wished they had better knowledge of study skills and financial aid before enrolling. Career plans varied, including further education, internships, and entrepreneurship.

Table 6. Alumni Post-Survey Responses (N = 4).

Number of Participants Selecting each Likert-Scale Response						
	Question: "I can…"	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Collaboration	Q1. be polite and kind to teammates	0	0	0	0	4
	Q2. acknowledge and respect other perspectives	0	0	0	0	4
	Q3. follow rules for team meetings	0	0	0	1	3
	Q4. make sure all team members' ideas are equally valued	0	0	0	1	3
	Q5. offer assistance to others in their work when needed	0	0	0	2	2
	Q6. improve my own work when given feedback	0	0	0	1	3
	Q7. use appropriate body language when presenting	0	0	0	1	3
	Q8. come physically and mentally prepared each day	0	0	1	0	3
	Q9. follow rules for team decision-making	0	0	0	1	3
Communication	Q10. use time, and run meetings, efficiently	0	0	0	1	3
	Q11. organize information well	0	0	0	1	3
	Q12. track our team's progress toward goals and deadlines	0	0	0	1	3
	Q13. complete tasks without having to be reminded	0	0	0	1	3
	Q14. present all information clearly, concisely, and logically	0	0	0	0	4
Creativity/ Innovation	Q15. Understand how knowledge or insights might transfer to other situations or contexts	0	0	0	2	2
	Q16. Find sources of information and inspiration when others do not	0	0	1	2	1
	Q17. Help the team solve problems and manage conflicts	0	0	0	2	2
	Q18. Adapt a communication style appropriate for the purpose, task, or audience	0	0	1	1	2
	Q19. Elaborate and improve on ideas	0	0	0	1	3
Belonging	Question	NO!	No	Yes	YES!	
	Q20. I feel comfortable at this school.	0	0	0	4	
	Q21. I am a part of this school.	0	0	2	2	
	Q22. I am committed to this school.	0	0	1	3	
	Q23. I am supported at this school.	0	0	2	2	
	Q24. I am accepted at this school.	0	0	1	3	

Six alumni participated in a focus group after their first semester at the university, providing additional insights. They expressed confidence in the 21st-century skills gained from the high school, especially in teamwork and public speaking, but felt less prepared in traditional subjects like math, having only completed precalculus. They noted the strong alumni network helped ease their transition to college and guided their career paths, but they were concerned about competing academically and navigating financial aid.

For the teacher data, 15 teachers completed the pre-survey, and 23 completed the post-survey. Teacher experiences are summarized in Table 7.

Table 7. Teacher Survey Participants

	Years	Pre-survey	Post-survey
Teaching Experience	Less than 1	1	2
	1-3	3	4
	4-6	3	2
	7-10	2	2
	11-14	4	3
	15+	0	3
Polytechnic High School Experience	Less than 1	4	5
	1	2	3
	2	2	4
	3	1	0
	4	4	4

During the pre and post survey, results from the Likert Scale questions stayed relatively similar, with some decreases and increases in means and standard deviation. Teachers were asked to select a level of agreement to indicate how they feel about their students' abilities in areas relating to 21st century skills. The survey results are presented in Table 8 and results around teachers' perception of student belongingness in Table 9.

Table 8. Teacher survey results related to 21st Century Skills.

Construct	Statement (I believe my students...)	Pre-Survey (*N = 15*)		Post-Survey (*N = 23*)	
		Mean	Std Dev	Mean	Std Dev
21st Century Skills (Collaboration)	are polite and kind to teammates	3.75	1.01	3.60	0.66
	acknowledge and respect other perspectives	3.50	0.96	3.80	0.40
	follow rules for team meetings	3.25	0.92	3.20	0.81
	make sure all team members' ideas are equally valued	3.08	0.86	3.30	0.71
	offer assistance to others in their work when needed	3.42	0.86	3.50	0.59
	use appropriate body language when presenting	3.42	0.95	3.15	0.73
	come physically and mentally prepared each day	2.92	0.95	2.85	0.65
	follow rules for team decision-making	2.92	0.86	3.20	0.68
	Improve my own work when given feedback	3.83	0.69	3.60	0.86
21st Century Skills (Communication)	use time, and run meetings, efficiently	2.58	1.04	2.55	0.59
	organize information well	2.83	0.90	2.85	0.73
	track their team's progress toward goals and deadlines	2.83	0.99	3.20	0.51
	complete tasks without having to be reminded	2.67	1.03	2.55	0.86
	present all information clearly, concisely, and logically	2.92	0.86	2.95	0.64
21st Century Skills (Creativity)	understand how knowledge or insights might transfer to other situations/contexts	3.42	0.86	3.05	0.74
	find sources of information and inspiration when others do not	3.33	1.03	3.20	0.81
	help the team solve problems and manage conflicts	3.42	0.76	3.05	0.74
	adapt a communication style appropriate for the purpose, task, or audience	3.17	0.80	3.00	0.77
	elaborate and improve on ideas	3.50	0.65	3.40	0.73

Note. A Likert-scale of 5-Points was used: 5=Strongly agree to 1=Strongly Disagree.

Table 9. Teacher survey results related to Student Belongingness.

Statement (I believe my students...)	Pre-Survey (*N = 15*)		Post-Survey (*N = 23*)	
	Mean	Std Dev	Mean	Std Dev
Feel comfortable at this school	3.17	0.55	3.10	0.54
Are a part of this school	3.50	0.50	3.40	0.58
Are committed to this school	2.92	0.64	2.75	0.43
Are supported at this school	3.50	0.65	3.25	0.43
Are accepted at this school	3.42	0.64	3.30	0.46

Note. A Likert-scale of 4-Points was used: 4=YES!; 3=Yes; 2=No; 1=NO!

Teachers expressed confidence in their students' 21st-century skills, particularly in teamwork and communication, but had concerns about students' time management and autonomy. Although students felt a sense of belonging at the school, some experienced declines in commitment and comfort.

Research question 1 examined how the innovative polytechnic high school model, centered on industry-driven design challenges, impacted students' preparedness for college and careers in terms of 21st-century skills, belonging, and aspirations. The data indicated that students felt more confident in their 21st-century skills but faced challenges with college readiness in traditional academic subjects due to curriculum adjustments and reliance on online supplements. Students also reported a strong sense of belonging at both the high school and the collaborating university. Additionally, the school model appeared to influence college and career aspirations by encouraging students to pursue projects aligned with their interests and seek relevant credentials.

Research Question 2

As for research question 2, to explore the challenges and successes associated with an innovative polytechnic high school model from the viewpoint of former students, a focus group session was arranged with six alumni who had completed a semester at the collaborating university. As for the teacher's perceptions of the successes and challenges, the post-survey data was analyzed. The following themes were derived from the participants' perspectives on the model's challenges and accomplishments.

Alumni Focus Group Challenges

Alumni challenges were identified as 1) Academic Preparedness (Mathematics), 2) Personal Learning Time Purgatory, and 3) Innovation for the Sake of Being Innovative. These themes are detailed below, with supporting comments from participants responses collected during the focus group. As a note, all comments were transcribed verbatim, and therefore may have grammatical errors, repetitions, or filler words. The literature documenting guidelines for conducting focus groups and analyzing the resulting data emphasized the importance of verbatim transcriptions in order to fully, and more accurately, capture participants' perceptions (Hays & Singh, 2011).

Academic Preparedness (Mathematics).

Participants perceived their academic preparedness as mediocre, specifically after they had transitioned to the collaborating university. It is important to note that participants themselves decided to make a distinction between being "*academically prepared*" and being "*prepared in*

other ways," which is discussed more in the successes section. All participants within the focus group rated their academic preparedness a "5" or "6" (on a 10-point scale). For example, one participant mentioned "*academically, math wise, all these different things... I feel like I was not prepared at all.*" Naturally, participants discussed the challenges they faced with the academic environment that had been provided by the high school model, specifically describing the school subjects as being "*underserved,*" especially mathematics, which students perceived to be "i*ncredibly underserved and not prioritized nearly enough*." Another participant shared this sentiment, saying; "*My other subjects were not very technical, so I guess it wasn't as difficult, but math is —definitely was —it wasn't structured as well.*"

Participants mentioned several reasons for this perspective, including the school model's approach to "*traditional subjects*" which initially entailed students completing modules for mathematics courses through an online learning platform, during their Personal Learning Time. One student described the difficulty of the online learning supplement approach, stating: "*I think that it was a hindrance when it came down to it and they needed to put more time into traditional teaching structures for math, I believe*."

Based on their responses, the school model eventually shifted to completely 50% online, and 50% project-based before the students' junior year in high school, which contributed even more to students' poor perception of the model's approach to traditional academics, and of their own academic skills. While participants readily discussed their views on their academic readiness, they appeared even more inclined to propose potential remedies for the obstacles encountered. For example, students stated: "*AP classes, honors classes. That would be very helpful because I know a ton of people, they took AP classes, and they get to skip a bunch of stuff. And I'm stuck in the bottom,*" with another participant following this statement by saying, "*honors classes and AP classes would definitely help a lot.*"

At the university level, participants recommended transitioning from scantron exams for mathematics courses to traditional-style tests to allow for partial credit opportunities. This shift would enable the recognition of students' efforts and problem-solving approaches, rather than solely relying on scannable answer sheets. One participant expressed frustration with the current system, stating: "*If you hear me out, partial credit on math. So, they do Scantrons — Wrong answer, wrong bubble. Yeah, even if you did it right even until the very last moment.*" While acknowledging that implementing this change might necessitate hiring more teaching assistants for exam grading, participants believed it would result in fewer students failing mathematics courses.

Personal Learning Time Purgatory.

In the school model, Personal Learning Time (PLT) refers to the designated period for students to independently engage with modules (each covering various subjects and accessible through the school's online learning platform) while receiving support from teachers as required. During the focus group, participants conveyed how what initially resembled "just a study hall" with a "work at your own pace" philosophy gradually evolved into a "purgatory" of unstructured hours during the school day. They detailed several challenges associated with this approach, citing instances where they were unsure of what tasks to undertake, occasionally found themselves lacking assignments, experienced reduced motivation to work due to the flexible pacing and lenient deadlines, and felt burdened by the sometimes-unrealistic expectations placed on

students during this period. For example, one participant described their experience in PLT during their senior year, stating: *"Moving through, especially in my senior year, I got to a point where, where the workload was still pretty heavy. But I was able to get it done in a reasonable amount of time that I just had this PLT time where I just kind of had nothing to do*".

One student described PLT as, "*Just big 4-hour blank spaces that you would sit down and work, but — like hell*" while another described the model's approach to PLT, saying it was like: "*I'm gonna put you in a pool and hope you swim.*" Lastly, the model's "*go at your own pace*" approach to learning during this time, was "*kind of what bit some people in the ass*" when it came to meeting deadlines. Participants provided possible solutions to combat these challenges, such as providing more defined structures during PLT ("*just add some more structure, more classroom —not like —more support from the teachers*"), allowing students to return to personalized scheduling, and aiding students in "*learning self-discipline*" (including "*deadline responsibility*").

Innovation for the Sake of being Innovative.

The innovative nature of the high school model necessitated various new educational approaches to achieve its objectives. While participants appreciated several innovations like industry partner projects and passion projects, they also critiqued the model's tendency to sometimes prioritize innovation without clear purpose. They pointed out what they perceived as unnecessary innovations, such as competency grades and the substitution of traditional classes with online learning supplements. One participant expressed frustration with the absence of traditional courses within the model, *stating: "I felt like the lack of any traditional classes was unnecessary.*" One student described their frustration, saying: "*Don't just not have traditional classes because traditionalism is terrible. You know, it's been working. There're parts of the traditional learning model that obviously work. We see it in our college lecture halls. We see it in all the schools around the world, you know —parts of our learning style are still very effective, you know?*"

Another participant believed the model competencies were an unnecessary innovation within the model, describes this view, saying: "*They have competencies —were in those projects. They have like three competencies —like three, like focus areas that they have, and there's 20 total. And you can either get like an A, B, C, or like a non-completion F grade for uhm—I hate that idea. Because it's just another kind of grade that they have to —you have to focus on other than the traditional grade that they have for in [ONLINE LEARNING PLATFORM].*" Although respondents seemed to believe there were unnecessary innovations within the school model, students took time to provide some suggestions for addressing this challenge. For example, regarding the online learning platform used for all core classes, participants suggested a blend of the use of the online learning platform and traditional courses, while also keeping the model's focus on industry partner challenges and passion projects. One student described this approach, saying: "*So, bring that back for math and all of these other largely knowledge-based subjects and still keep the project cycles there. You know, the project cycles are really what gave me all the critical thinking skills that I have today.*"

Another respondent agreed with the blended approach, saying: "They need to —yeah, they need to add traditional classes for like math and some sort of sciences. But they also, I think they—I do like the projects that the teachers set up."

Another participant then agreed with this, stating: “So, I think they should, they should keep [PASSION PROJECTS] but also try to fit in the traditional stuff as— as well. And not just have those online, and ‘just if you need them well, you can just schedule it—If you need them. Just we'll —just have you, you know, do it online all the time.’ Because I think the projects are a good idea.”

Regarding the competencies, respondents believed it was an unnecessary part of the model. One student described their solution, “T*hey need to get rid of that.*” Ultimately, participants believed the model had many great components, but the model needed to “*kind of go back a little bit stop trying to be so needlessly innovative, I think, and they have a great school.*”

Alumni Focus Group Successes

During the focus group, participants also took time to describe some of the successes they experienced, through attending the school model, and once they had transitioned to the university. Several themes related to student successes were identified, including 1) There's More than One Way to Measure Success, 2) School Model Pedagogies, and 3) No Regrets.

There's More than One Approach to Success.

Participants in the focus group made a clear distinction between being "*academically prepared*" and being "*prepared in other ways.*" While they acknowledged feeling less prepared academically due to their attendance at the innovative school model, they emphasized the non-academic successes the model offered them. One participant expressed this sentiment, stating, "*I still think that we are prepared a lot of other ways*." Interestingly, all participants rated themselves higher in terms of being "*prepared in other ways*" compared to their academic preparedness. For instance, one participant highlighted the importance of the model's emphasis on self-responsibility, stating: "*It kind of taught you a lot of self-responsibility*." Others echoed this sentiment, citing skills such as time management, self-advocacy, and social interaction as areas where they felt confident. These skills were often linked to the unique opportunities provided by the school model, such as project cycles and online learning platforms. One participant even attributed their critical thinking skills to the project cycles, stating, "*the project cycles are really what gave me all the critical thinking skills that I have today.*"

School Model Pedagogies.

Despite some challenges, participants recognized several aspects of the model's pedagogical approaches as successful. They appreciated the opportunities for personalized learning, particularly through passion projects. One participant described the variety of options available, stating, "*If you want to do Ethics Bowl, or like, it's like a debate class, you could do it.*" Additionally, participants valued the freedom to create their own schedules and pursue extracurricular interests during Personal Learning Time (PLT). Some used this time for projects or career-related activities, such as IT certifications. Despite critiques, all participants expressed satisfaction with their decision to attend the model, emphasizing its positive impact on their personal growth and proactive mindset.

No Regrets.

Despite encountering challenges associated with their involvement in an innovative polytechnic school model, both during their high school years and after transitioning to higher education,

participants remained resolute in their choice to enroll in the model. They intentionally concluded the focus group on a positive note, underscoring their favorable perception of the model. This sentiment was exemplified by one student's remark: "*Overall, my— because it seems like a mainly focusing on the critiques. Overall, I have mainly a positive attitude around it—it really prepared me for a lot of stuff. If I went to LOCAL SCHOOL], I don't know what kind of person I'd be but— so going to [INNOVATIVE SCHOOL MODEL], it definitely made me a greater person, a more proactive person so...* "

Other participants followed this comment by sharing a similar perception: "Yeah, and we're bashing the system, but we're not bashing — I think it was the right decision, it just could have been better."

Based on the data, participants perceived there to be advantages to pursuing a traditional high school education, however, students also believed their choice to pursue a nontraditional high school experience had its own advantages. For example, one participant describes this perspective: "So, in a way, having a more traditional school would have helped, but also, that being like, nontraditional did help, as well, because it —because it ended up forcing me to like, you know, think for myself, actually go through and ask questions, if there's something that I'm interested in, like, go and research and become —instead of just having like something you thought about for like, for like a, like a day or so, then just gave up." Despite the "risks" taken— as some students described— by attending the novel school model, all students concluded the focus group by sharing that they had no regrets in their decision to attend the model.

Teacher Identified Challenges

As for the teacher post-survey responses topics around challenges such as 1) Student Autonomy and 2) COVID-19 arose.

Student Autonomy.

Teachers observe students grappling with autonomy, noting instances of its misuse within the school model. One teacher highlighted the model's emphasis on autonomy, requiring substantial patience. The design-cycles emulate real-world problem-solving scenarios, fostering student-driven progress and necessitating a shift in the traditional teacher role. Balancing support for student autonomy demands adaptation and patience from both students and teachers. Described as a "*non-traditional school, where a lot of the student's academic work is self-paced and online, and the school day is split between some classes, independent work, and passion projects*." Therefore, "*self-motivated, driven students who can work without an adult always pressuring them to complete their work*" would be a good fit within this type of school model. However, from the teachers' responses it seems that few students are challenged to fit within this "*mold*" at their age level. However, teachers perceive that few students at their age level effectively adapt to this model's expectations.

COVID-19.

For example, it was mentioned that "*the transition from post-covid was hard*" getting back from online school to in person school came with its challenges. One of the teachers said they felt "*like they are starting from scratch in some ways*" at the beginning of the school year, coming back from online school because some students fell "*even further behind during the pandemic than other*" and another mentioned "*this was a challenge this year as we had to spend a lot of*

time on their basic tasks from a couple of years ago instead of being able to focus on grade level content and up." As students had their classes through a computer screen for an extended period of time, the in-person responsibilities and requirements for a design-based STEM curriculum were hard to translate in a virtual environment. This resulted in a low level of accountability for the students which challenged them in the more "*self-directed learning*" school model. It was reported that "*from over a year of COVID-learning, students are not prepared to be in a classroom and pay attention with their cell phones and other devices.*" Therefore, coming back face-to-face with students, the teachers experienced some challenges for the school model such as dealing with "*behavioural issues due to being under-socialized through eLearning*." One recommendation given by a teacher was to have a strong sense of self before teaching in this school model, knowing who you are in an educational model that demands the most from the educator was seen as advantageous in this setting.

Teacher Identified Successes

As for the teacher's post-survey responses around the successes of the school year, the following themes arose: 1) Commitment to Innovative Education and 2) Building Meaningful Relationships.

Commitment to Innovative Education.

Teachers were enthusiastic about providing students with authentic, hands-on learning experiences, integrated STEM lessons, and connections with real projects alongside industry/community partners, fostering design/project-based learning aligned with student interests. As per one of the teachers, the polytechnic model allows for "*innovation in all areas*" The teachers felt that this school provided innovation opportunities for the students within the learning experiences including innovation opportunities for teachers with decision making related to the school and the curriculum. As this model is new and striving to foster 21stcentury skills through authentic learning experiences, a teacher described this school as a "*pillar for school change*" This innovative educational model is looking to link "a*cademic connections of why we're doing what we're doing*" to bring context to problem solving through design-based learning. Additionally, the teachers are given "*creative control*" of their learning activities, and one teacher wrote "*I am flexible, innovative, collaborative*" The teachers are conveying innovation within the school and students are growing through a new type of educational experience. During the design-cycles, the teachers see their role as needing "*to be adaptable to changes throughout the design process,*" indicating that educational innovation for the teachers is constant They also noted significant progress among first-year students in their design cycle pitches/presentations. This innovative educational model encourages innovation in all areas, providing opportunities for students and teachers to engage in decision-making related to the curriculum and school operations. Additionally, teachers emphasized the importance of building relationships with students to support their understanding of their roles as valued members of society, assisting them in achieving their goals and fostering a collaborative learning environment.

Building Meaningful Relationships.

One of the common themes that teachers wrote about was their excitement to be in-person for this school year. The strain on building relationships between students and teachers was challenging during the pandemic. As one coach wrote, "*I am happy to be back in the building and able to make connections with my students not just in a virtual capacity.*" The teachers

want to have meaningful relationships with their students, which is viewed as necessary to help students progress through the design-cycles and their passion projects. Additionally, teachers wrote about the school, saying that "*getting to know the polytechnic high school team, its students, and its philosophy for reinventing education*" was something that they enjoyed about the school year. Forming connections and creating relationships makes a difference in such an open-ended and self-directed educational environment. A coach wrote that "*I am happy that we are all able to get back into the building and be able to work together face to face.*" Overall, teachers were excited for the in-person school year, especially at an innovative school where relationships, innovation, and education come together for hopes of secondary educational transformation.

Summary of Research Question 2 Results

Research question 2 aimed to explore the challenges and successes encountered by students and teachers in an innovative polytechnic high school model centered on industry-driven design challenges. Analysis of data obtained from the alumni focus group and survey responses revealed various insights. Students highlighted challenges such as a perceived lack of readiness for college-level academic coursework, the presence of unnecessary innovations within the school model, and dissatisfaction with personalized learning time. Conversely, students reported successes including a sense of belonging at the collaborating university, opportunities for personalized projects aligned with their interests, increased confidence in 21st-century skills, and perceived benefits of pursuing a nontraditional high school education. While teachers struggled with student autonomy and COVID-19, there were also successes such as enjoying the ability to try innovative pedagogy, and to build meaningful relationships.

Conclusions, Discussions, & Recommendations

This study explored perceptions of an innovative polytechnic high school model regarding college and career readiness and identify its associated challenges and successes. The focus on a high school model integrating STEM experiences, personalized learning, and industry-driven design challenges, data collected from student, teacher, and alumni surveys and an alumni focus group. Findings reveal the polytechnic model, which emphasizes industry and community-driven design challenges, presents both opportunities and challenges. Participants described the model as evolving, with the metaphor "building the plane while flying it" capturing their experience. Alumni, navigating a constantly adapting curriculum, noted both positive and negative aspects. They valued personalized learning and industry connections but faced challenges in traditional academic subjects and adapting to higher education's demands. Teachers observed strong student skills in collaboration and communication but expressed concerns about time management and autonomy.

The model's strengths included fostering 21st-century skills and belonging, while its weaknesses involved challenges with traditional academics and reliance on online learning. Participants appreciated real-world project opportunities but felt underprepared for conventional academic expectations. There was a notable tension between innovative learning methods and traditional academic rigor, impacting students' readiness for standardized tests and higher education coursework.

The study highlights the dual nature of innovative educational models: they offer significant benefits in personalizing learning and enhancing real-world skills but also face challenges in

balancing these with traditional academic requirements. The findings underscore the need for ongoing evaluation to determine whether the advantages outweigh the risks and to inform future iterations of such educational models.

Recommendations include enhancing communication and collaboration between high schools and partnering universities to better prepare students for higher education. This includes increased involvement and clearer communication from the university regarding academic expectations and support resources for transitioning to a lecture based higher education learning model. Additionally, refining the academic approach is crucial; addressing gaps in traditional academic preparation, particularly in math and science, by integrating more structured instruction alongside design challenges is necessary. Balancing online learning with face-to-face instruction can help with academic preparation. Future research can focus on longitudinal studies to track alumni experiences over time and explore additional perspectives from academic advisors and parents. Investigating how students from different academic paths within the university or other institutions respond to the model and studying the long-term impact of such models on educational innovation, can offer valuable insights. This study provides insights and recommendations for improving the balance between innovative learning approaches like this polytechnic model, and traditional academic requirements to better support student success in higher education and beyond.

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