Reinventing Secondary School: An Investigation of a Polytechnic High School Model Focused on Industry/Community-driven Design Projects

Deana Lucas, Purdue University
lucas158@purdue.edu
Vanessa Santana, Purdue University
vsantana@purdue.edu
Dr. Greg Strimel, Purdue University
gstrimel@purdue.edu

ABSTRACT

Higher education and industry leaders seem to continuously call for transforming the way learning occurs within schools to better meet the needs of students, society, and the workforce. Many attempts have been made to address these calls such as increasing integrated STEM programming in schools, providing after-school robotics activities, as well as developing novel school models. One such innovative model, the focus of this study, is a polytechnic high school model developed in collaboration between a public research-intensive university and several industry/community partners. This model was developed to be implemented in urban settings with an emphasis on serving minoritized youth through design project cycles created with local industry/community partners rather than through subject-specific classes. It can be valuable to investigate a school model that has been created to have this design-based learning approach as its central focus. The purpose of this exploratory study was to understand 1) how teachers perceive the influence of the school model on the learning of students from diverse backgrounds and 2) how teachers view their own experiences working within the school model. This study examined pre/post teacher surveys to provide insights into how the teachers believe the school model is working with respect to students' ability to perform within this style of design-based instruction and any challenges faced by the teachers to implement the school model. This information can help to inform those who seek to provide different learning environments for students through restructuring schools around industry/community-focused design projects. This paper will introduce the components of the polytechnic school model, detail the emphasis of the industry/community-driven design cycles, highlight the methodology used, present some preliminary findings, and discuss insights and recommendations for secondary schooling.

Key Words: Design-based learning, Secondary School Transformation, Integrated STEM Education.

1. INTRODUCTION

Secondary education provides students with a universal foundation of learning through curriculum designed to help every student achieve similar levels of understanding or designated learning outcomes (Leland & Kasten, 2011). 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 school's function and curriculum has been structured. However, it can be viewed that siloing of the disciplines deprives, or at least makes difficult to provide, opportunities for students to make valuable and authentic connections between disciplines (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 in turn have a direct impact on student learning. As a teacher's professional knowledge is linked to education quality and student performance, it can be important to bring more holistic views to the classroom that reflect the multifaceted and interconnected world of today (Evens et al. 2018). 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). Many countries are calling for the enhanced preparation of students to become creative, innovative, and ready to meet the hallmarks of competitive and emerging industries (Partnerships for 21st Century Skills, 2016). The Partnership for 21st Century Skills (2016) posits that developing skills such as thinking critically to make informed judgements; solving multidisciplinary and open-ended problems; creativity and entrepreneurial thinking; communicating and collaborating; making innovative use of knowledge, information, and opportunities; and taking charge of financial, health, and civic responsibility are a necessary outcome for schools throughout the 21st century. These demands for 21st century skills are also in alignment with the increased attention to the implementation of design-based and/or problem-based learning to support integrated STEM (science, technology, engineering, and mathematics) teaching in secondary schools (Yuxin & Williams, 2013).

There are many theorized solutions to address the demands for 21st century skills through education, such as increasing integrated STEM curriculum to providing after-school STEM programs, or even developing types of STEM focused school models. This study takes a deep dive into one such school model which is an innovative polytechnic high school model that has been developed in a collaboration between a public research-intensive university and several industry/community partners. This polytechnic high school model is positioned to allow students to develop their 21st century skills through integrated STEM learning that provides them with practical training and real-world experience through authentic design project cycles. These design project cycles, some of which are depicted in figure 1, are developed with local industry/community partners and are used as the focus of instruction rather than the traditional subject-specific classes. This model was developed to be implemented in urban settings with an emphasis on serving minoritized youth through this integrated and design-based approach. As integrated STEM learning through design projects has become an emphasis for many schools around the world (Yuxin & Williams, 2013), investigating this polytechnic school model and its

design-based learning approach can be valuable for understanding opportunities for improving STEM education.

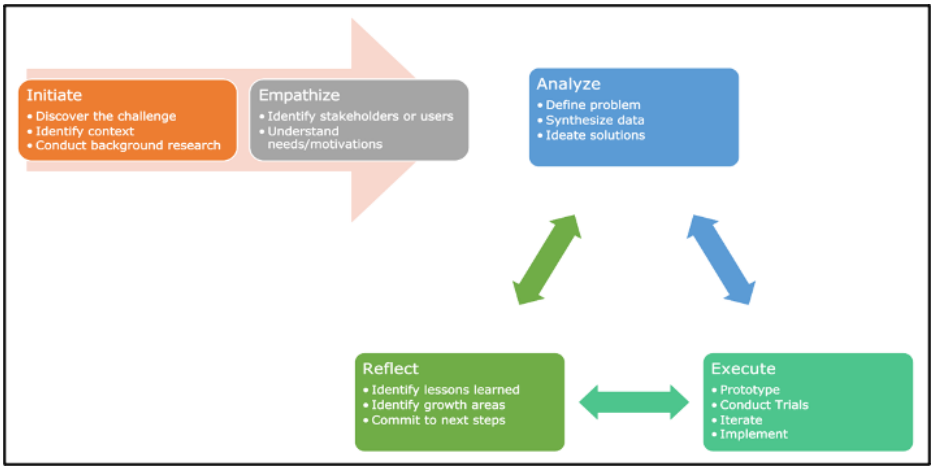
2. POLYTECHNIC SCHOOL MODEL

The polytechnic high school model was designed to integrate STEM learning within personalized learning environments that require hands-on learning (Santana, 2022). Students complete design-cycles every six weeks, where every cycle consists of a different industry or community partnered project, depicted in figure 1. The students are then guided through these design cycles using the school's version of a design process (see figure 2). At the end of each cycle, student teams pitch their solutions to the design challenge to a variety of school, community, and industry stakeholders (Santana, 2022). This design-based learning approach is positioned to encourage students to solve authentic problems that are complex and multifaceted. The teachers, who are referred to as *coaches*, collaborate with industry/community representatives to create the design-cycles in a way that aligns with the academic standards and provide students with rigorous STEM activities that reflect problems or opportunities faced outside of the classroom in the "real world" (Santana, 2022). In addition to industry driven projects, students also can take part in passion projects, which are projects designed by teachers, but chosen based on students' interests (Santana, 2022).

This blend of industry/community partnered design cycles and passion projects take the place of traditional classes usually offered in secondary education such as mathematics, language arts, science, and social studies. Instead of the traditional eight class periods a day, or four classes rotating on a block schedule, this model allows students to establish their own schedules and attend supplemental workshops for obtaining the knowledge necessary for the design cycle and the learning objectives (Santana, 2022). The workshops are referred to as dojos, which are small group lessons that supplement, or address problems related to, a specific topic relevant to the design-cycle (Santana, 2022). When students are not attending a dojo, they are using *personal learning time* (PLT) to work through other educational requirements. The students then use their design-cycle experiences, dojo attendance, and PLT to demonstrate their mastery of the school's core competencies. Then, as Santana (2022) explains, students who graduate from this school with a 3.4 GPA and a 1050 SAT score are admitted into the collaborating university. This school model was founded in 2017, and has grown to be implemented across three schools, with plans for more.

Figure 1.
Example Design-Cycles

Figure 2.
The Polytechnic High School Model Design Process – Note. This graphic was adapted from the school's website.



3. RESEARCH QUESTIONS

The polytechnic high school model is positioned to provide an innovative approach to education to address the demands for 21st century skills and integrated STEM instruction. While this positioning is notable, it is important to study how this school model is being implemented and its potential influence on student learning to enhance our understanding of school transformation efforts. The following research questions were developed to guide this study:

(i) What are the influences of a polytechnic high school model, which is centered on industry/community-driven design challenges, on students learning (i.e., 21st century skills and sense of belonging) as perceived by the teachers/coaches?

(ii) What are the challenges and successes of a polytechnic high school model, centered on industry-driven design challenges, from the teacher's/coaches' perspective?

4. METHODS

The research questions were answered using data from the 2020-2021 school year that was collected via the school's survey provided in tables 2 and 3 below. Teachers completed these surveys at the beginning of the year, and at the end of the year. To better understand teachers' perceptions of their student's learning, these surveys included Likert-scale items relating to 21st century skills (*Creativity*, *Communication*, and *Collaboration*) and sense of *Belonging*. Additionally, the surveys included open-ended response questions that were used to examine teachers' attitudes toward the school year. During the pre- and post-survey, the duration of years

the coaches have been a part of this polytechnic high school were collected as well as their overall teaching experience.

The data from the Likert Scale items were organized and re-worked into numerical values to answer the research questions ("Strongly Disagree" = 1 to "Strongly Agree" = 5 for the 5-point items, and "NO!" = 1 to "YES!" = 4 for the 4-point items). To measure the constructs of *Collaboration*, *Communication*, and *Creativity*, Likert scale items adapted from Kelley et al.'s (2019) 21st Century Skills Survey, were used. Similarly, to measure the construct of *Belonging*, Likert scale items adopted from Anderson-Butcher and Conroy's (2002) Belonging Scale, were also used. The open-ended questions were coded to find additional themes to support the Likert Scale data.

5. PRELIMINARY FINDINGS

A total of 15 coaches completed the pre-survey and 23 coaches completed the post-survey. The complete demographics are provided in Table 1.

Table 1. *Teacher Survey Participants*

	Years	Pre-Survey	Post-Survey
Teaching Experience	Less than 1	1	2
	1-3	3	4
	4-6	1	2
	7-10	2	2
	11-14	4	3
	15 +		3
Polytechnic High School Experience	Less than 1	4	5
	1	2	3
	2	2	4
	3	1	0
	4	4	4
Total		15	23

During the pre and post survey, results from the Likert Scale questions stayed similar, with some decreases and increases in means and standard deviation. Coaches 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 2.

When looking at the responses, the most consistent categories the teachers/coaches felt confident in their students' abilities, were *be polite and kind to teammates* (mean pre-survey 3.75, mean post-survey 3.60), *improve their own work when given feedback* (mean pre-survey 3.83, mean post-survey 3.60), *acknowledge and respect other perspectives* (mean pre-survey 3.50, mean post-survey 3.80), and *elaborate and improve on ideas* (mean pre-survey 3.50, mean post-survey 3.40). These areas highlight what the teachers/coaches perceive to be their students' strengths with the 21st century skills. During the pre and post survey, there were two categories that scored the

lowest, which allows us to gather that teachers/coaches do not feel too confident about their students' abilities to *use time and run meetings efficiently* (mean pre-survey 2.58, mean post-survey 2.55) and *complete tasks without having to be reminded* (mean pre-survey 2.67, mean post-survey 2.55). This polytechnic school model encourages autonomy; however, teachers/coaches may not see that reflected in their students.

Teachers/coaches were asked to select a level of agreement to indicate how they feel about five assertions related to belongingness of their students within the school model (see Table 3). The consistent categories with the highest means were; *I feel that students are a part of this school* (mean pre-survey 3.50, mean post-survey 3.40) and *I feel that students are accepted at this school* (mean pre-survey 3.42, mean post-survey 3.30). One category, *I feel that students are supported at this school* (mean pre-survey 3.50, mean post-survey 3.25), resulted in a high mean from the pre-survey and dropped by 0.25 in the post-survey, which is a larger decrease than all the other means in the belongingness category. As for the categories with lower means, there were two consistently low statements: *I feel that students are committed to this school* (mean pre-survey 2.92, mean post-survey 2.75), and *I feel that students are comfortable at this school* (mean pre-survey 3.17, mean post-survey 3.10). The coaches' views of students' belongings seemed to decline from the beginning of the year. The responses elicited from the Likert Scale questions reveal a little about the successes and struggles of the polytechnic school model. To aid in providing a holistic understanding, coaches were asked open-ended questions as well.

The open-ended questions in the pre-survey asked: *What are you most worried about for this school year* and *what are you most excited about for this school year*. The post-survey questions asked teachers/coaches: *What did you like most about this school year; how would you describe this school to other teachers and what would you feel the need to tell them; reflecting on your experience this school year, what new challenges did you encounter;* and *reflecting on your experience, what could make a student a good fit for this school.* Using the answers to these questions, themes of perceived challenges and successes emerged from the teacher's/coaches' experiences teaching in a polytechnic high school.

Table 2. *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 or 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 3. *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	0.5	3.40	0.58
are committed to this school	2.92	064	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!

The challenges that emerged were related to the school's curriculum, autonomy of the students, and Covid-19 struggles. These themes which are described in the following sections, were consistent throughout the answers provided to the survey open-ended questions.

5.1. Polytechnic Curriculum

The teachers/coaches mentioned their struggles with navigating the polytechnic school's curriculum. Teachers/coaches found that differentiating their work with the design-based curriculum to meet the needs of all their students was a challenge. One coach had written that they were scared to let "certain academic skills and expectations slip through the cracks" as they navigated the more open-ended projects. The coaches in the school are also given a good deal of creative freedom with the curriculum, which caused some concerns at the school. For example, the coaches worried about not being able to fit important academic topics in the six-week design cycles. Traditional schools typically have a pre-established curriculum given to teachers, usually with some ways to differentiate. However, the polytechnic coaches are following an innovative educational approach that requires more work and agility to adapt and plan for learning without a pre-established curriculum. A saying is that the coaches are "building the airplane while flying it" regarding the learning experiences. Some coaches reported being the only instructor with their background/disciplinary knowledge in the school, and another reported having to learn how to teach two new subject areas in which they were not trained. While these issues may pose challenges for implementing a new school model focused more on open-ended design cycles, some coaches noted the opportunity that this experience brings. For example, one coach mentioned that they are okay with trying out new lessons that they might not have had the opportunity to try before while another coach mentioned that they were enabled to teach more content in which they had a passion for. There are benefits and challenges to this model, and it requires coaches to go outside of their comfort zone. While there is not truly a defined curriculum, the coaches are finding innovative ways to provide students with engaging learning experiences.

5.2. Student Autonomy

This polytechnic school model takes an approach that requires students to hold themselves accountable for their learning. Coaches have seen students struggle with their autonomy. For example, coaches responded that students misuse their autonomy and that the school model "supports a high level of autonomy, and you need to have a tremendous level of patience." The design-cycles reflect real-world problem solving and design thinking scenarios, hence the students are often driving their own progress. The typical classroom dynamics are challenged with this model, and at times, the role of the "*teacher/coach*" needs to shift. Coaches finding the balance in their role while supporting student learning and autonomy, requires change and patience from both students and coaches. One coach described the model 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 coaches' responses it seems that few students are challenged to fit within this "mold" at their age level.

5.3. Covid-19 Struggles

The survey data were collected at the end of the 2020-2021 school year, which was still amid the Covid-19 pandemic. Therefore, many of the coaches' challenges at the school were centered on this topic. 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 coaches 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 coaches 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 coach 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.

While the coaches faced challenges, they also experienced successes in the school. These successes came in the form of student learning and growth, the ability for educational innovation, and the building of meaningful relationships. These themes, which are described in the following sections, were consistent throughout the answers provided to the survey open-ended questions.

5.4. Student learning and growth

Coaches were excited about providing students with authentic, hands-on learning experiences, integrated STEM lessons, and connections with real projects with industry/community partners. Coaches identified that through these learning experiences students were able to pursue their interests in the form of design/project-based learning. Additionally, one of the coaches mentioned how much progress the first-year students made in their design cycle pitches/presentations. Coaches were also "building relationships with the students in order to assist them in understanding their role as a student and a valued and productive member of society." Establishing a positive rapport with the students and assisting them in "crossing the finish line" seemed to allow students to work hard and reach their goals. In an educational model that requires innovation at every corner, everyone is working to learn and grow. The coaches indicated that "the care is so deep at our school for our students. It is really cool to be a part of." The coaches reported their desire to see the students succeed and how education within this polytechnic school goes beyond solely lecturing to students. The coaches believe that within this school students can learn and grow along with their coaches.

5.5. Ability for Educational Innovation

The polytechnic high school model, as per one of the coaches, was described as fostering "*innovation in all areas*." The coaches felt that this school provided innovation opportunities for the students within the learning experiences including innovation opportunities for coaches with decision making related to the school and the curriculum. As this model is new and striving to foster 21st century skills through authentic learning experiences, a coach described this school as a "*pillar for school change*." This innovative educational model is looking to link "*academic connections of why we're doing what we're doing*" to bring context to problem solving through design-based learning. Additionally, the coaches are given "creative control" of their learning activities, and one coach wrote "*I am flexible, innovative, collaborative.*" The coaches are conveying innovation within the school and students are growing through a new type of educational experience. During the design-cycles, the coaches see their role as needing "*to be adaptable to changes throughout the design process,*" indicating that educational innovation for the coaches is constant.

5.6. Building Meaningful Relationships

These surveys were administered during the 2020-2021 school year, therefore some of data are reflective of the Covid-19 pandemic. One of the common themes that coaches wrote about was their excitement to be in-person for this school year. The strain on building relationships between students and coaches 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 coaches 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, coaches 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, coaches 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.

6. RECOMMENDATIONS AND DISCUSSION

Due to this being the preliminary review of data from the school, the authors recognize there are limitations to the results. However, the data that were reviewed can provide some insights related to school transformation toward a less standardized educational approach. Understanding how the coaches perceive the educational model has the potential to enhance our understanding of the implications related to implementing integrated STEM learning through design project cycles as the central focus of secondary learning. While this school approach can appear to provide authentic, hands-on learning experiences, connections with community/industry partners, a less siloed school culture, practical experiences promoting 21st century skills, and student autonomy in learning, it can also require increased cognitive demands on teachers and students in regard to

self-directed learning, minimize experiences with developing disciplinary expertise, and a disconnect with the way in which post-secondary learning occurs. Therefore, further research can be beneficial to better understand the college/career readiness of students experiencing this type of school model as well as their success in post-secondary education. In addition, it can be beneficial to study the implementation of such a school model overtime. For example, the authors have experienced changes in the model since the survey collection and have noticed some shifts toward "more traditional" educational approaches. These shifts can be interesting to determine what works and what doesn't as well as how educational innovations can be overwhelmed or stifled by cultural/societal norms as these schools do not exist outside of established social systems. Continuing research on this polytechnic high school could continue to provide insight into how less structured schools and design-based learning can be implemented appropriately to support student success.

7. CONCLUSION

As calls for 21st century skills are only becoming more necessary, there appears to be opportunities to transform secondary schooling to better meet the demands of our complex world. Meeting these demands through educational transformation can be challenging as schools exist within complex and interconnected societal and educational systems. Research is key in understanding how educational models, such as this polytechnic school model, function, and influence learning in positive, challenging, and indifferent ways. From the preliminary review of survey results, the data revealed coaches believe students within that school are working respectfully in teams, iterating their work, and most importantly learning and growing. However, it is a challenge to help students manage their autonomy within design-based learning and develop time management skills. Overall, this preliminary review indicates two main perspectives. First, that high school students can struggle with the amount autonomy that is provided through the design cycles and passion projects. And second, that students can benefit from teamwork, collaboration, and relationships with community, industry, and school partners. The information from the preliminary results can be used as an insight into the challenges and successes of a designed-based approach to integrated learning from the coaches' perspective. Educators, school systems, and other stakeholders can potentially use this information as insight into the polytechnic school model and to inform decisions related to educational transformation.

8. REFERENCES

Anderson-Butcher, D., & Conroy, D. E. (2002). Factorial and criterion validity of scores of a measure of belonging in youth development programs. Educational and psychological measurement, 62(5), 857-876.

Evens, M., Elen, J., Larmuseau, C., & Depaepe, F. (2018). Promoting the development of teacher knowledge: Integrating content and pedagogy in teacher education. *Teaching and teacher Education, 75*, 244-258. https://doi.org/10.1016/j.tate.2018.07.001

Hodge, K.A., & Lear, J.L. (2011). Employment Skills for 21st Century Workplace: The Gap Between Faculty and Student Perceptions. *Journal of Career and Technical Education, 26*(2), 28-41. ERIC -

EJ974462 - Employment Skills for 21st Century Workplace: The Gap between Faculty and Student Perceptions, Journal of Career and Technical Education, 2011

Kirwan, M., Bhatti, A. J., Pacey, V., Gray, K., & Dean, C. M. (2022). Overcoming silos: a sustainable and innovative approach to curriculum development. *Education Sciences*, *12*(6). https://doi.org/10.3390/educsci12060375

Leland, C. H., & Kasten, W. C. (2011). Literacy education for the 21st century: It's time to close the factory. *Reading and Writing Quarterly*, *18*(1), 5-15. https://doi.org/10.1080/105735602753386315

Partnership For 21st Century Skills – Core Content Integration. (2016). 21st_century_skills_standards_book_2.pdf (marietta.edu)

Santana, V. (2022). *Risks and rewards of reshaping high schools: A case study of a novel polytechnic high school model and student perceptions entering college* [Master's thesis, Purdue University – West Lafayette].

Yuxin M., & Williams, D. C. (2013). The Potential of a First LEGO League Robotics Program in Teaching 21st Century Skills: An Exploratory Study. *Journal of Educational Technology Development & Exchange*, *6*(2), 13–28.