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Reinventing High School: Understanding the Challenges and Successes of Transforming Education to Meet Student, Society, and Industry Needs

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ABSTRACT

Efforts to revamp existing educational systems and approaches result in various new models in STEM education. Accordingly, a new urban public charter school, located in a Midwest state in the United States, was established in partnership with the state's land-grant university to create a transformed integrated STEM educational environment characterized by industry-focused and design-based learning to help prepare students for the future of work and learning. This article presents findings from an exploratory study that examined the experiences of teachers and administrative staff of this innovative high school (IHS) during the first year of school operation. A purposive sample of 16 teachers and administrators from the IHS completed a semi-structured interview and a focus group. Several themes—related to the experiences during the first year of the school—from the interviews with the participants emerged including: (1) developing novel approaches for planning and implementing design-based learning cycles, (2) facing challenges with personalized learning, (3) establishing methods for creating authentic and industry-driven learning experiences, (4) addressing challenges with open-ended learning, (5) confronting concerns about competencies that are not measured through standardized assessments, (6) struggling with teacher burnout, and (7) challenging traditional school systems and facilities with integrated learning environments. Based on these findings, potential implications, considerations, and future directions for the implementation of innovative industry- driven, design-based educational approaches are provided.

Note. *To preserve anonymity the name of the high school has been generalized and the acronym IHS will be used throughout*

Key Words: *Design-Based Pedagogy, STEM Teacher Experiences, School Reform, STEM Integration, Secondary Charter Schools*

INTRODUCTION

Imagine a high school that is inspirational and challenging, where failure is treated as a great opportunity to learn and not as something to fear. Learning occurs inside and outside of the school walls; instruction comes seamlessly from school staff, industry mentors, and peers; and students have the opportunity to work on, and solve, problems that happen in their neighborhood, city, state, nation, and world. Students leave high school knowing how to learn, and are comfortable with the idea that the majority of problems are open-ended and require creativity, innovation, and flexibility to solve. This vision, which is centered on design thinking across the curriculum, guides a recently opened urban innovative high school (IHS) located in a Midwestern state in the United States that was established in partnership with the state's land-grant university. The new school, launched on July 31, 2017 with a highly diverse initial class of 157 ninth grade students (70% under-represented minorities), was founded on several core principles, including: (a) teachers using evidence-based best practices focused on the integration of core academic subjects with authentic STEM topics, (b) school faculty and staff supporting competency-based personalized learning that is academically rigorous and flexible to adapt to each student's needs, (c) students solving real-world design challenges and projects, and (d) students connecting knowledge and skills to possible careers through internships and industry certifications. In addition, the mission of the school is to develop graduates, specifically from underserved communities, that are prepared to meet the evolving workforce needs of industry and their communities by providing a learning environment that is student-centered with non-traditional teaching and learning techniques. This includes an investment from the land-grant university that includes providing a more accessible pipeline to the regional workforce and post-secondary learning. To do so, this university has established an agreement to (1) provide direct admission to one of the university's colleges to any of the graduating high school students that meet the admission criteria, (2) ensure student exposure to the campus throughout the school year, and (3) enable the high school to leverage university programs, such as summer camps, for extended learning opportunities.

Although these efforts represent a potentially novel approach for school reform, a key focus should be on investigating these disruptive school reform ideas to better understand their impact they have on the educational beliefs of teachers and staff, on classroom practices, and on pedagogies. Recognizing the stark contrast between the stated core principles of the the IHS and more traditional K-12 educational approaches, an understanding of the lived experiences of the teachers at the IHS related to interacting with students, integrating design thinking across the curriculum, and enacting these core educational principles can be important to inform future school reform initiatives. Furthermore, the results of such an investigation can help gather rich insights into the overall experience of teachers and staff with this innovative teaching/learning approach and may assist in the identifying areas for further development – both in terms of curriculum and instruction as well as the professional development of teachers. To achieve this, research was conducted into the first-year experiences of the IHS teachers and administrative staff through a qualitative study composed of 16 semi-structured interviews and a focus-group session. An understanding of their experiences may provide insights and contribute to the overall knowledge base around teacher development, pedagogy, and teacher experiences in integrated and highly open-ended STEM learning environments.

LITERATURE REVIEW

This research investigated the experiences of teachers and administrators during the first year of the IHS – a unique public charter school founded on design-based instruction, STEM integration, and personalized learning experiences. The following review of literature on charter schools, STEM integration, and related pedagogies provides a foundation for both the methodology and discussions in this study

Charter Schools

Founded on school choice reform (Teasley, 2017), charter schools have sought to increase the choices and variety of elementary and secondary learning environments for students across the United States. A public charter school, by definition, is a public school that, in accordance with an enabling state statute, has been granted a charter exempting it from selected state or local rules and regulations (Gruber, Wiley, Broughman, Strizek & Burian-Fitzgerald, 2002). These schools often provide smaller class sizes than the National average of 16:1 teacher to student ratio (Snyder, de Brey, & Dillow, 2018). While there continues to be a debate on the effectiveness and accessibility of public charter schools, the number of these school have continued to increase. The National Alliance for Public Charter Schools (2018) has reported that there are more than 7,000 charter schools across the country that enroll nearly 3.2 million students. However, the impact of the approaches taken by nontraditional schools continues to be unclear (Bohte, 2004; Bracey, 2005; Greene, Forster, & Winters, 2006); this necessitates investigation into the outcomes of these schools to ensure effective efforts toward enhancing student learning.

STEM Education & Pedagogies

The debate around the purpose of K-12 education in the United States has begun to shift from the long-standing notion of preparing students for college and higher education, to a new focus on preparing student to become “college-and-career ready” (Daggett, 2010). Over the last decade, the culmination of the K-12 education was to adequately prepare students for college education. However, this has gradually been changed as a result of changes in the workplace, in which global competition and emerging technologies are requiring skills and knowledge sets that are often higher than, and fundamentally different from, those required for higher education (Daggett, 2010; Steed, 2018). Arguments are even being made that students who earn college degrees will find that even with a degree they do not readily qualify for the job they intended to pursue (Dean, 2017). It seems too few students are prepared for college or a career, and even fewer are prepared for both (Daggett, 2010; Royster, Gross, & Hochbein, 2015). It should go without saying that students need, and should have, the appropriate skills and knowledge required to pursue college education, but more important they need to know how to apply technical knowledge and skills acquired in an increasingly highly skilled workforce (Daggett, 2010; Koen, Klehe, & Van Vianen, 2012) and continuously evolving workplace as a result of the rapid integration of artificial intelligence, digitalization, and automation (Akdere, 2019, Jesuthasan & Boudreau, 2018).

While the American school system has rushed to implement the “best practices” in educational reform as a response to global competition (Bybee, 2010) (e.g., practices stemming from the Sputnik-spurred education reforms of the 1960s), and more recent policy implementations such as the No Child Left Behind Act (2002) and the America Competes Act (Civic Impulse, 2018), many students are still lacking the skills and knowledge they need to be successful, not only in college, but in the workforce (Deloitte & The Manufacturing Institute, 2018). The issues of preparedness, which span all fields of education, are keenly prevalent in science, technology, engineering, and mathematics areas (Dickman, Schwabe, Schmidt, & Henken, 2009). STEM fields, which often rely on both technical and applied skills such as problem-solving/critical thinking, creativity/innovation, and collaboration/teamwork, are seen as vital components for educational reforms, improvements, and adjustments (Casner-Lotto, & Barrington, 2006). Many posit that the STEM education received by American students—specifically in K-12 schools—may not be at a level that enables workers to satisfy current and future workforce needs (Pew Research Center, 2016). The concern over how to adequately prepare students and foster an effective education in STEM areas has led to curricular and pedagogical emphases around integrated STEM education and open-ended/design-based pedagogies.

Integrated STEM education.

Within the larger arena of STEM education there are several competing theories, ideas, and approaches (Prince, & Felder, 2006). One of these, integrated STEM education, emphasizes the intentional integration of two or more of the STEM areas through the use of a relevant and authentic context, such as engineering and technological design problems (Kelley & Knowles, 2016). Sanders (2009) explains the notion of integrative STEM education as "…integrative STEM education includes approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (p. 21). Wells and Ernst (2015, p. 1) further this idea with an emphasis on using technology and engineering design scenarios to teach content from multiple areas; they argue that "Integrative STEM education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels." This integrative approach is founded on the idea that there should be learning *between* school subjects, not only *within* each of them - learning that happens as students incorporate knowledge and content from each area within the broader context of an open-ended challenge. As Sanders (2009) suggests "the basic point is that the ideas and practice of science and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others" (p. 23). To this effect, Harris and deBruin (2018) assert that removing a siloed approach to traditional discipline division increases productivity and encourages creativity throughout a student's academic experience. Use of these methods can provide a basis for the application of subject-area knowledge and encourages the practice of cross-cutting skills through problem-based learning activities.

Problem-based learning.

One of the student-centered pedagogies commonly employed in integrated STEM settings is problem-based learning (PBL). PBL began as an instructional strategy used in medical schools, in order to give students, the opportunity to confront authentic problems faced in health care (Barrows, & Tamblyn, 1980) and has been lauded as an effective approach aimed at preparing students for both academic and career success (Boud & Feletti, 2013). The Buck Institute for Education defines PBL as a "teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge" (2018). PBL is a student-driven, teacher-facilitated approach to learning (Bell, 2010) that often includes (a) a driving question, encompassing worthwhile content that is meaningful and anchored in a real-world problem; (b) investigations and *artifact creation* that allow students to learn concepts, apply learned information, and represent held knowledge; (c) collaboration among students, teachers, and others in the community; and (d) the use of technological tools (Krajcik, Blumenfeld, Marx, Bass, Fredricks, & Soloway, 2011).

***Design-based learning*.**

Closely related to PBL, design-based learning (DBL) is another instructional method widely used within science and engineering classrooms. This pedagogical approach engages students in developing solutions to authentic design problems while reflecting on the learning process (Mehalik, & Schuun, 2006). Like PBL, many DBL approaches begin by posing a problem for the students to solve and, in DBL, this problem often centers on a design challenge (Mehalik, Doppel, & Schunn, 2008) in which students have to generate ideas, learn new concepts necessary for its solution(s), build models and test them, analyze, rethink, revise, and repeat any of these steps until a solution is found (Kolodner, et al., 2003).

PROBLEM STATEMENT

In light of the widespread efforts related to STEM education, integrated STEM pedagogy, PBL/DBL, and innovative approaches to schooling, this study investigated the initial experiences of teachers and administrators following the completion of the first-year implementation of a new innovative educational approach at the IHS. Accordingly, this study focused on the experiences of teachers and administrators with respect to their efforts, pedagogical practice, and educational perceptions within this public charter school learning environment designed to promote academic excellence through industry-focused experiential learning (e.g., PBL/DBL), specifically with underrepresented minority students who want to pursue STEM-related careers. Explicitly, this effort sought to understand how teachers and administrators perceived and experienced the integrated PBL/DBL in the context of authentic, industry-driven problems during the first year of the IHS. The focus was on their perceptions and experiences of establishing, implementing, and improving innovative pedagogical approaches related to design thinking through integrated STEM learning.

RESEARCH QUESTIONS

This study, which involved semi-structured interviews with teachers and administrators and a focus group session, centered on the experiences of the study participants. The interviews and focus group were guided by the following research questions:

RQ1: What are the perceptions of the [IHS] teachers and administrators around how relevant problem-based learning experiences can be best constructed to support student learning and other desired outcomes in an integrated education setting?

RQ2: What are the first-year experiences of the [IHS] teachers and administrators related to implementing an innovative design-based learning pedagogy within a public charter school?

STUDY CONTEXT

The IHS is a STEM-focused public charter school located on the east side of a major urban city in a Midwestern state. The high school, which was launched through a collaboration between a land-grant university, an urban public-school district, and the city itself, is guided by a specific charter to prepare students for college and careers while providing skills necessary for an evolving workforce through reinventing the traditional high school experience (IHS, 2019). At the time of the study, the students were in the process of finishing the first school year. During the first year, the school housed a total of 20 teachers and administrative staff and 157 ninth-grade students with over 70% of the student population identified as underrepresented and/or underserved minorities.

The instructional format, in-class experiences, teaching style, leadership, and goals for IHS graduates are a few of the differences geared toward helping the population of underrepresented and underserved students thrive and acquire valuable STEM knowledge and life skills. For example, instead of rotating between subjects, students follow a multidisciplinary approach that integrated academic standards through six industry-sponsored design challenges throughout the year. Each challenge varied from 4-6 weeks in length and, during the challenge, students did not “go to class” but instead, they scheduled themselves into teacher-designed workshops and small seminars (called dojos) on a weekly basis with the intent of preparing themselves to complete the challenge and demonstrate their competence in specific areas of learning.

The curriculum for the school was competency-based and had a strong emphasis on “learning by doing” to promote in-depth knowledge, applied skills, and experiences in the workplace for its graduates (IHS, 2019). Specifically, the scope of the high school curriculum was divided into three parts:

- The foundational year (comprising of the first year),
- The core (composed of the second and third year in the school), and
- The capstone (the fourth and last year).

Plans for the school dictated that during the foundational year (9th grade, ages 13-15), students are instructed in the school’s design thinking process (See Figure 1 on page 6) and work to master core content standards, knowledge, skills and processes that will transfer to all STEM career paths. The stages of design, taught at the school, include a) Initiate: students discover the challenge and conduct research; b) Empathize: students identify key stakeholders and seek to understand their needs; c) Analyze:

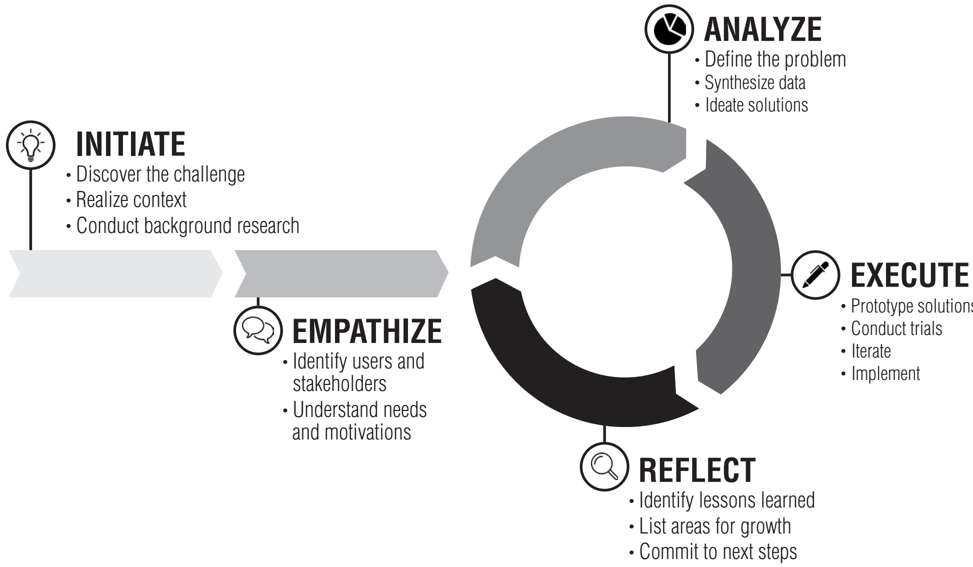

Figure. IHS design thinking guide for industry-sponsored design challenges (XQ, 2018).

students further define the problem and being brainstorming solutions; d) Execute: students prototype solutions in multiple iterations; 5) Reflect: students assess the effectiveness of their design and make plans for improvement. In addition to design, during the core years (10th and 11th grades, ages 15-17) students apply foundational competencies and learn content, knowledge, skills, and processes specific to career pathways of their choice. Lastly, during the capstone year (12th grade, ages 17-18), students both apply the learned foundational and core skills and demonstrate mastery of the competencies required to successfully fulfill their post-secondary career/education paths.

Student schoolwork during the first year was guided by six industry-sponsored design challenges—also known as cycles (a snapshot of the six cycles for the 1st and 2nd years of the school are provided in Table 1). At the inception of each cycle, all students were grouped in *Personal Learning Communities* (organized groups of faculty and students) and attended a convocation, or "cycle kickoff," in the auditorium. These convocations, led by the *learning coaches* (teachers), provided students with some highlights from the previous cycle (e.g., awards for the top ranked teams), and presented students with a context for the problem they would be addressing in their next cycle. Learning coaches also used the cycle kickoffs to present the "big ideas" for learning during the cycle – core concepts the students should master while working on the problem. These big ideas covered standards from all subject areas; as an example, the big ideas for Cycle 6 included topics such as quadratics, the historical events and impacts of the September 11th events, engineering ethics, science and society, and distance and displacement. The intent behind the big ideas was that they would serve as a guide to students as they begin to think of problem statements, gather information, conduct research, develop solutions, create prototypes, communicate information, evaluate their own learning progress, and demonstrate their competence in each big idea area.

This investigation into the experiences of the teachers at the IHS immediately followed project *Cycle 6* in Year 1 for 9th grade students, which engaged the students in a DBL challenge around improving transportation. During the kickoff for this cycle, the students viewed a video that provided the context for the design challenge and discussed innovations in transportation (such as water taxis in Paris). The video asked students to imagine a place they would like to live and whether it should be accessible, easy to get around, and/or technology-based. The video concluded with the following sustainability-related design challenge sponsored by a local public transportation company: *How can the city improve its public transportation network to support and sustain a vibrant economic and social environment?*

After the video, students had an opportunity to build empathy with "end users" and community partners. A guest speaker from the industry sponsor (a city public transportation organization) provided students with a background of the transportation systems, the organization's mission toward long-term

Table 1. IHS Design Challenge Cycles.

			Year 1			
Cycle	**1**	**2**	**3**	**4**	**5**	**6**
Overarching Design Challenge	How might we use emerging technologies to reshape an existing industry?	How might we move people or products further, faster, cheaper, and more efficiently?	How might we optimize a machine?	How might we create or enhance products or services to help community members lead healthier lives	How might we power the world's innovation with great efficiency and access?	How does Indiana develop a connected and viable transportation infrastructure?
Local Industry-Sponsor	Automotive Manufacturer	Airline Company	Motorsports Company	Hospital	Utility Service Company	Public Transportation Company
			Year 2			
Cycle	**1**	**2**	**3**	**4**	**5**	**6**
Overarching Design Challenge	How might technology take one of your solutions form Year 1 to the next level?	How might we move people or products further, faster, cheaper, and more efficiently?	How might we create or enhance products or services to help community members lead healthier lives?	How might we create new and better food sources to feed nine billion people by 2050?	How might we extend the healthy human lifespan worldwide?	How do we allocate $500 billion to meet the world's biggest challenges?
Local Industry-Sponsor	University Student Innovation Organization	Airline Company	Hospital	Agricultural Science Company	Pharmaceutical Company	Non-profit Charity Organization

Note. *The design cycles and industry sponsors have been generalized.*

sustainable transportation practices, and most important, the issues they faced and strived to address by 2022. Following this empathy-building step, the students brainstormed and asked the speaker follow-up questions as they worked to define their own problem statements, and generate potential solutions for the identified transportation challenges. For example, one student asked the speaker whether their transportation organization considered population growth when creating or improving their service lines, while another student asked how the company addressed safety concerns for riders. Throughout the remainder of this cycle the learning coaches offered workshops and "dojos" for students geared toward assisting students in learning the concepts related to the cycle's big ideas as they complete the cycle challenge. The learning coaches also visited students throughout the cycle during open-blocks of "design time" to answer questions, provide resources, and direct students while developing solutions to the challenges.

METHODS

Prior to *Cycle 6*, IRB approval was obtained and all 20 teachers and administrative staff members were informed about the study, recruited for participation, and provided with consent forms. The recruitment resulted in 16 of the 20 teachers/administrative staff participating in the semi-structured interviews and seven participating in the focus-group session. The interviews and focus groups were held immediately after the *Cycle 6* kick-off event. The consenting teachers and administrative staff members came from diverse backgrounds: Some had industry experience, prior teaching experience, and others had professional experiences (see Table 2 on page 8). Regarding the participants, 69% were female, whereas 31 % were male. The averages in both years in education and years in teaching were over 11 years. All participants began employment at the high school at the same time and were in the process of concluding their first year at the school. The interviews and focus groups were conducted with both teachers (called learning coaches at the school) and administrative staff and covered a variety of related research questions. The data collection took place over the course of three consecutive days at the school site with two days for semi-structured interviews and one additional day for the focus group discussion.

Semi-structured Interviews

Participant interviews were conducted over the duration of two days and averaged 30 minutes in length. The semi-structured interviews included six questions centering on the participants' thoughts, perceptions, experiences, and lessons learned during the first year of employment at the IHS. Berg (2001) explained that semi-structured interviews involve a series of questions around specified topics that are asked of each participant which allow researchers freedom to probe beyond the answers to the prepared questions to further clarify and understand responses. To ensure fidelity in the results, a semi-structured interview protocol (see Appendix A), which included questions and an introduction, was followed in each interview. The researchers emphasized questions that reflected an awareness and understanding of the phenomena associated with this study from the interviewee's perspective (Berg, 2001). Table 3 displays the semi-structured interview and focus group questions. Each interview audio was recorded and later transcribed for analysis. In addition to the audio recordings, the member of the research team conducting the interview also took field notes during the interviews. These notes were collated and used later in data analysis as a form of finding triangulation.

Table 2. Participant Demographics

ID	Gender	Content Area/Teaching Background	Years in Education	Years Teaching (Public School)	Self-described role at the PPHSI
1	F	English Language Education, Elementary Teacher, Curriculum and Training Development, Research	16	8+	Personal Learning Coach / English Language Learners (Teacher)
2	M	Chemistry Teacher, Maker Space and Design Thinking teacher	10	10	Lead Learning Coach / Design Thinking (Teacher)
3	F	Mathematics	8	8	Personal Learning Coach / Math Coach (Teacher)
4	F	English, Journalism, Psychology	20	20	Personal Learning Coach / Humanities Coach (Teacher)
5	F	Science (Biology)	17	17	Personal Learning Coach / Student Sponsor (Teacher)
6	F	Science, Long-term Teacher Substitute	10	8	Personal Learning Coach / Science (Teacher)
7	F	Science (Biology, Life Science, Integrated Chemistry & Physics)	15	7	School Principal
8	M	Mathematics	2	N/A	Innovation and Learning Strategist, Director of Innovation
9	F	English	9	9	Personal Learning Coach / Humanities (Teacher)
10	M	Behavioral Neuroscience, Adult Education	2	2	Dean of Culture
11	F	Special Education Teacher, Special Education Specialist	20	14	Special Education Coordinator
12	F	Adult Education, Life Coach, College Transition Counselor	6	N/A	College Career Coordinator
13	F	Engineering, Manufacturing, Curriculum Development, Homeschooling	5	N/A	Personal Learning Coach / Engineering (Teacher)
14	M	Aerospace Engineering, Mathematics, Physics, Technology	10	10	Design Team Coordinator
15	F	Deaf and Hard of Hearing Education, Mathematics, Science, Social Studies, Administration	17	17	Personal Learning Coach / Mathematics (Teacher)
16	M	Political Science	11	N/A	Community Outreach Coordinator

Focus Group

Following the semi-structured interviews, all consenting teachers and staff were invited to attend a 90-minute focus group session on a subsequent day. A total of seven individuals participated in the focus group which was facilitated by two members of the research team. During the focus group, the questions from the semi-structured interviews were used again (see Table 3) in conjunction with the focus group protocol (see Appendix B) to prompt discussion around the guiding research topics. The researchers simply provided relevant prompts and follow–ups during the focus group session with the explicit intent to facilitate the conversation on the questions among the participants. Audio from the focus group session was recorded and transcribed in preparation for analysis. Upon completion of the data collection, the audio recordings were transcribed by a third-party transcription service and all transcriptions were conditioned by removing non-related data (i.e., words such as "er," "um," and "uh".) The transcription analysis, for both the interviews and the focus group, involved a three-step analysis process: (a) descriptive coding (Saldaña, 2015), (b) thematic coding (Charmaz & Belgrave, 2012), and (c) analytic coding (Saldaña, 2015). NVivo software (QSR International, 2015) was used as a tool for organizing the emerging themes during the analysis. Each of the three outlined steps included the following efforts:

1. ***Descriptive Coding***
   The transcripts were read and separated into distinct thoughts. Each thought was then described using a single phrase or word which represented the overall expression of the thought based on recommendations in Saldaña (2015). Following this step, the thoughts were grouped by similar descriptors and finally similar descriptors were grouped together into larger descriptor groups (Table 4 shows an example of this process).

Table 3. Semi-structured Interview and Focus Group Questions

1. How are problem-solving experiences best constructed to support student learning and other desired outcomes in integrated STEM education?
2. What challenges do teachers identify when planning integrated STEM activities in the school setting?
   a. Are their additional challenges in the urban school settings?
3. How should integrated STEM experiences be designed to account for educators' varying levels of experience with integrated learning and STEM content?
4. What are the benefits and trade-offs of delivering integrated STEM education experiences with collaborative teams of educators who have expertise in different STEM disciplines?
5. What synergistic STEM concepts and practices are learned better through integrated STEM education approaches than via disciplinary-focused approaches?
6. If you were given the opportunity to change things at IHS, what would you do the same or differently to support student learning and other outcomes in integrated STEM learning?

Note. Questions adapted from recommendations in the STEM Integration in K–12 Education: Status, Prospects, and an Agenda for Research *Report by the National Academy of Engineering and National Research Council (2014).*

Table 4. Descriptive Coding Process Example

Interview Responses	Initial Descriptive Coding	Assigned Group Descriptor Phrase
So, one thing that we found when we approached this the first time, the questions were chosen on the basis of… "Hey, these are the people willing to work with us, are excited to work with us." So we got six of them more or less. There was a little bit of thinking directed at sort of spreading them across industries and challenges, but not that much. There was a little bit of that, but a lot of easier easily accessible partners.	Poor Planning	
Now the partner spread wasn't too, too bad. But some of the questions were pretty awful. And they were bad because we went to the partner and basically just said, "What's your challenge?" And it was great. And it was a genuine challenge that they're interested in, but it wasn't necessarily the thing that could drive all of the standards that we wanted to teach students.	Ill-Suited Challenge	Difficulties Faced In Cycle Implementation
And so, it was a very disconnected experience for a student of like, "Okay. I'm solving a [Automotive Industry Sponsor] challenge. So I'm learning this thing about logistics or an assembly line or automation or robotics, but my project's supposed to be how can I get a better workforce," and so like these two things are so disparate that it really didn't connect for them. And so it was this disconnecting experience of the challenges running one direction and then what we actually wanna teach are running in another direction.	Disconnected Experience	

2. ***Thematic Coding***
Step two of the coding process involved using the data from step 1 to identify salient themes emerging from the data. This process involved (a) identifying potential categories, (b) relating data to other data, and (c) iteratively cycling through the process of identification, relation, and grouping until representative themes emerge. This process was undertaken for all data—with the descriptive coding process results serving as a guide and starting point. In each case a "parent" code was identified from the initial group descriptive coding process and descriptor phrases. In several instances multiple ideas/themes emerged which related to a single parent code; in these cases, a more specific child code was also identified in addition to the initial parent code/theme. Figure 2 illustrates an example of this process with our data.

3. ***Analytic Coding***
The final step to the analysis of the qualitative data involved considering the emergent themes, parent, and child codes from the second step and conducting a further analysis to identify messages or aggregate emergent concepts. This approach was guided by techniques put forth by Saldaña (2015). Specifically, the relationships between the identified themes and the guiding research questions was analyzed. An illustration of the coding process and examples of the results from the analytic analysis and coding is included in Table 5.

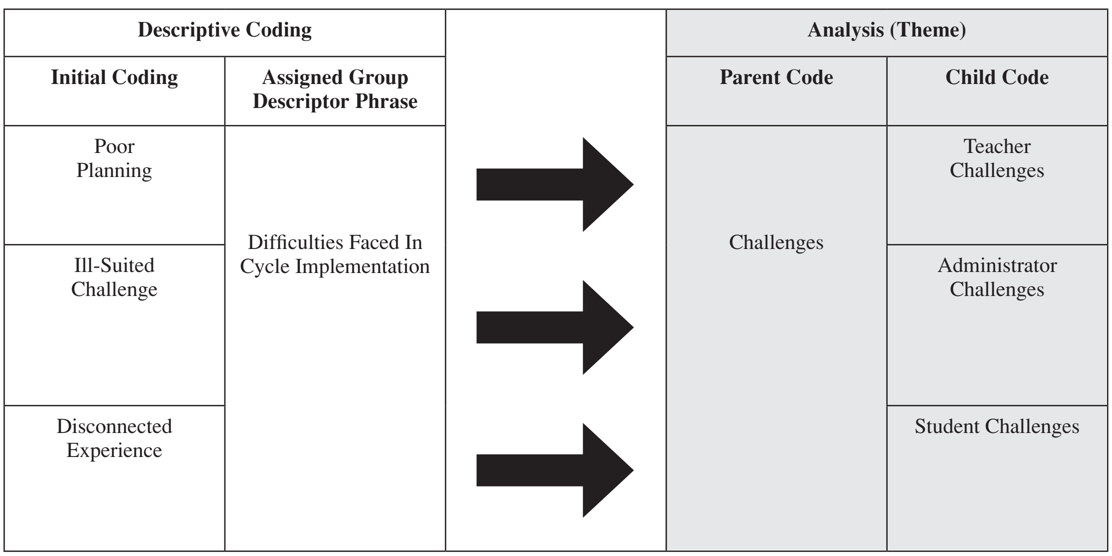

Figure 2. Descriptive and thematic coding process

Table 5. Analytic Coding Example

Theme (# codes)	Sub-categories (# codes)	Example
Instructional Design (114)	Benefits (75)	*Every cycle, we change things…It'll be so much healthier for them to grow up in an environment where they see adults fail and try different things, and I think that's what we're kind of prepping them up for.*
	Tradeoffs (39)	*But that is one of the tradeoffs. We can't address it until it's already become a problem. It's already become a habit. And the student is now discouraged, because they practiced it.*
Student Learning Outcomes (135)	Successes (79)	*The coaches are coaching around the design process and my, let's see, I have clear data on that students are improving on the design process.*
	Concerns (56)	*So we tried to do things very disjointed, and when in between we focused so much on integration and mashup that even that mashup became too forced.*
Educational Challenges (132)	Teacher (110)	*And when I came here, I kinda enjoy chaos…when I came here, started to see things around, kids don't know what they're doing, teachers don't know what they're doing, the principal does not know what she's doing, so everybody is like there's a method to this madness, there's a method to this madness. But then, it was kinda hard to see that method at first.*
	Student (22)	*These kids have probably never heard of designed thinking, and you're adding that into a completely different school structure overall.*
Needs for Success (85)	Teacher (37)	*It's definitely the case that to construct these things, to construct really genuine, really authentic you need to have a high caliber level of staff that probably is not the level one could expect on a kind of average basis of who you'd be able to hire.*
	Student (48)	*Maybe start giving them a little structure, and then start taking it away, and taking it away. I think all of us have talked about that with freshmen particularly. This free-for-all was very difficult.*
Cycle Configuration (81)		*So, what are the parts of an instructional model? So, you will hear things like workshops… checkpoints… focus areas or back space content…beginning of a project cycle, in the middle of a project cycle, in the end of a project cycle…kick off, and in the beginning, and at the end, you throw a pitch. You'll hear things like the product of a design thinking sprint. You'll hear things like the design team…*
Integration (46)	Natural (23)	*But science, I can have them read a scientific article and then write, a response to it. Or I can have them summarize something that is, you know, related to the cycle that has to do with the science standards. So, those marry very easily.*
	Forced (23)	*On the flip side I think that math and science, they're very difficult to integrate without that effective because you're not hitting (a) all of your standards.*
Teacher Outlook (36)		*You're not just teaching the one piece of content I think is why I'm probably ruined for traditional education to ever go back to a regular classroom.*
Collaboration (22)		*I think one of the things here in school is that everybody comes with an experience and background. Nobody is a fresh, first year or second year teacher…All the teachers are pretty much experienced and I would say I was the only one who's never worked with high schoolers before...It has its pros and cons, again, like having all people coming with rich experiences and backgrounds, and trying to see where they come from, trying to implement here, that same thing here.*
Design Challenge Nature (9)		*It seems much more genuine...the question itself gets raised…but [they] are essentially going to be more grand challenge type questions.*

FINDINGS

The findings, taken from our three-step qualitative analysis process using the transcribed semi-structured interviews and the focus group session, are presented in line with each of the guiding research questions.

RQ1: What are the perceptions of the [IHS] teachers and administrators around how relevant problem-based learning experiences can be best constructed to support student learning and other desired outcomes in an integrated education setting?

Many participants referred to the evolving process of designing, presenting, and assisting students with the industry-driven problem-solving experiences at the beginning of their response to this question. The participants noted that the faculty and staff worked through a variety of approaches toward implementing these problem-solving experiences and that each problem "cycle" evolved throughout the first school year. At the time of the interviews, the participants had coalesced around the term "PL3" to describe the approach they were using in designing problem-based learning experiences. A PL3 described a team of three teachers working with a group of students on a given problem. The PL3s changed from cycle to cycle as did the students assigned to each new PL3. Accordingly, the analysis of the codes generated, through the three-step analysis process described above, revealed several insights into the perceptions of teachers around the problem-based learning experiences at the IHS—specifically, the perceived effectiveness of PL3s for student learning. These perceptions were organized into the two main themes of *instructional design* and *content integration*.

Instructional design.

The majority of codes (total codes = 229), derived from interviewee comments, related to their current approach to instructional design (114/229; 49% of coded responses) with teachers highlighting the benefits (75/114; 66% of coded responses) more often than the challenges (39/114; 34% of coded responses). Examples of the benefits related to the school's unique problem-solving design experience were highlighted and are included here (all interviewee names have been replaced with pseudonyms):

> **Susan:** *"we have developed a number called PL3's…there are three teachers [in a PL3] that are together with their students and then from that grouping we varied it so we've had every student either has to be an innovator, a communicator and a collaborator that's in one group."*

> **Bill:** *"It was in cycle three that this [problem-solving approach we've created] started…What that resulted in for the first time was teachers collaborating together to teach students about the challenge and what we learned from…*

> **Bill:** *"They're [students] working on research or they're planning out their interview questions and a coach [teacher] can pull up his or her laptop, the product management plan of those students and see, wow these are all yes or no questions. I'm going to go coach them about asking opened-ended questions during the interviews. That's much different than teaching, where these 50 students are watching a slideshow about how to do empty base questions and so, PL3 to me is the epitome of our instructional design model of coaching versus teaching and its working so well because we're learning from each other and modeling from each other."*

While many comments highlighted the benefits of the school's pedagogical approach, the participants also described the challenges associated with the unique design-based learning model being implemented at IHS. For example, some participants noted challenges related to differentiating learning within project cycles, managing and using the abundance of data to inform instruction, maintaining the connection between industry-driven projects and the concepts initially identified for each project cycle, and connecting novel approaches to teaching and learning to traditional summative assessments. The challenges are evident in the following quotes:

> **Susan:** *"It's really hard academically, to cater to the broad spectrums of students and where they are, and finding time to look at the data, look at the project cycle, check for understanding within the project cycle, and provide of the right interventions to get them."*

> **John:** *"…it was a very disconnected experience for a student of like, "Okay. I'm solving a [Industry Sponsor Deleted] challenge. So, I'm learning this thing about logistics or an assembly line or automation or robotics, but my project's supposed to be how can I get a better*

workforce," and so like these two things are so disparate that it really didn't connect for them…"

John: *"There's a disconnect between how you're gonna be tested and what, as a mathematician I actually want you to know about…"*

Integration.
The second theme which emerged was related to integration – of the comments related to integration (*N* = 46 comments) the comments were evenly split as to whether the integration of different content areas in the design project cycles was "natural" or "difficult." For example, some participants felt the pressure, seemingly from traditional high-stakes assessments, to move back toward a siloed approach to learning as they felt that developing expertise particularly in mathematics would be lost. On the other hand, some participants viewed the complete integration of subject matter through the industry-driven project cycles was the most genuine way to teach students and develop the skills necessary for the future of work. Example comments related to integration included:

Julie: *"…I was hearing that a lot from mentors, that they feel like math was maybe something that was going to be hard to be integrated into project cycles. It ... they felt like it ... that's the one thing that needs to probably remain by itself. A lot of my mentors felt that way."*

John: *"…I was hearing that a lot from mentors, that they feel like math was maybe something that was going to be hard to be integrated into project cycles. It ... they felt like it ... that's the one thing that needs to probably remain by itself. A lot of my mentors felt that way."*

RQ2: What are the perceptions of the [IHS] teachers and administrators around how relevant problem-based learning experiences can be best constructed to support student learning and other desired outcomes in an integrated education setting?

This second research question that guided the study was used to explore faculty and staff experiences, across the entire year, in implementing the unique problem-solving experiences at the IHS. The most common themes, emerging from participant responses to this question (total codes = 431), were related to the outcomes for students and the challenges for both teachers and students.

Student learning outcomes.
Related to student learning outcomes (135/431; 31% of coded responses) participants highlighted both successes (79/135; 56% of coded responses) and concerns (56/135; 44% of coded responses), which they connected with the unique approach of the IHS. Representative comments that illustrate these points, derived from the interviews, are included here.

Heather: *"We failed in the sense that we didn't accomplish all that we might have accomplished in a traditional classroom setting, as far as presenting the content and making sure, okay, checking off every single standard for everything, nine, ten, whatever…"*

Susan: *"So with that being said if we have a student that walked out the door today, would they intellectually be able to keep up in terms of the standards that we presented and have we taught that well enough so that they can hold their own, wherever it is that they happen to go?"*

Educational challenges.
When discussing educational challenges (132/431; 30% of the coded responses) participants highlighted the challenges faced by teachers (110/132; 83% of the coded responses) in addition to those commenting on the challenges faced by students (22/132; 17% of the coded responses). First, participants specifically highlighted that while they believed in the pedagogical model, the demands from both developing and implementing the school's unique approach were overwhelming. Second, the participants discussed the challenge for teachers to move beyond their prior teaching experiences within traditional schools to implement the new pedagogical practices of the school without falling back into old habits. Example comments related to these themes include:

Heather: *"Very candidly, I think that, there's a lot of loss of morale across the faculty there at the end of the year. A lot of people, I think that most people who are returning are doing so because they don't have something else to go to. But again, I think most of them do believe in the model, but a couple of them don't. Most of them do believe in the model, they're just burnt out."*

Bryan: *"I think in the workshops, in the dojos, I think we're still hitting them, but I think because a lot of the teachers aren't used to, all of our teachers aren't used to* *this type of curriculum, so what I see them doing is they're trying to hurry up in their workshops, deliver some of those content areas as much as possible…"*

Bryan: *"I think when [teachers have] been teaching for a while, it's a little bit more [difficult]. I think they learn [the new approach] quickly, but I do think that when stuff gets stressful, they fall back to- This is my classroom. This is what I'm going to do."*

Other comments related specifically to the educational challenges for students and their learning experiences with the unique approach used by the IHS. These included sentiments such as:

Jessica: *"Whereas, maybe a typical student may be able to figure that out on their own, or be told once and understand it…my students aren't able to get all that content in that one workshop. And that's been a struggle."*

Julie: *"I really feel like it was a lot thrown ...and asked of students and staff, with not a whole lot of time, so it required us to kind of be on our feet ready to move, ready to run and get things done."*

DISCUSSION

This research investigated the experiences of IHS teachers and administrators during the first year of the school. As the data was analyzed it was clear that many of the thoughts and perceptions shared by the participants were blended across/between theme areas. Therefore, the data for this work was evaluated through the lens of the research questions and also through the specific themes identified in the analysis of transcripts. The following section includes limitations of this effort and further discussion around several concepts which appeared throughout the data analysis including: *the PL3 approach, personalized learning, development of authentic learning experiences, open-ended learning, competencies not measured through standardized assessments, teacher burnout,* and *system and facility challenges.*

Limitations

The findings from this research are limited in scope to the setting described (i.e, school, teachers, staff, researchers, and so forth) and the analysis performed by the researchers. The experiences, biases, positionality, and perceptions of those involved are all recognized and inherently tied to the findings in this exploratory effort. Future efforts with new approaches, analysis, or investigators may yield different and important findings related to the identified research questions. Specifically, the qualitative approach used in this research could be strengthened through alternative approaches, researchers, or additional analysis. Despite the recognized limitations on this work several exploratory findings, themes, and directions for future research have been identified.

PL3 Approach

Considering the breadth of experience and training represented by the participants (see Table 2), it is not completely surprising that a unique approach to instruction emerged from the IHS environment. Called "PL3" (Professional Learning Group of 3 faculty) by the teachers and students, this approach involved a team of three teachers who worked with student groups on each design challenge cycle. The rationale behind this approach was that each of the teachers would bring their own expertise to bear while working with the students, in which students would receive information related to a wide variety of topics, viewpoints, and content areas. The faculty members who participated in this study spoke positively of this approach and noted that, while not perfect, this approach had helped significantly in terms of managing and teaching the student teams. The PL3 groups, unique to this school, appear to be a potentially useful approach for fostering faculty/student collaboration and covering a wide-range of topics related to student work and needs.

Personalized Learning

The study participants were quick to highlight the increased motivation in students who were provided with opportunities for "personalizing" or "customizing" their learning experiences. However, participants were similarly apt to point out that the students, who were more accustomed to a structured environment, also struggled with the sudden increase in autonomy. In more than one interview, the participants expressed concerns about the amount of learning that is actually happening as contrasted to traditionally structured schools and classroom environments. Many participants conjectured aloud during the interviews that they wondered how an IHS student would perform outside of IHS and how they would compare with their classmates. However, they often stated the belief that the students would be able to perform well in a design-based learning environment and within problem scenarios. While the participants believed students would perform well in open-ended environments, they were concerned as to how they might perform in traditional post-secondary courses, specifically in mathematics and science. Even though the additional autonomy provided to the students in this school was lauded as beneficial, it was also met with caution among the faculty in terms of the potential implications on future student success—especially in future environments with more "traditional" settings for education.

Development of Authentic Learning Experiences

The participants remarked that they saw value in the authentic opportunities for students – especially as compared with those available in traditional setting. The connection to industry partners was seen as positive and faculty specifically noted the benefit of having these partners to help develop real life challenges for the students to pursue. Prior to meeting with industry partners to discuss connections, the teachers worked together to identify a "big idea" that could be taken to industry partners. In meeting with industry partners, these "big ideas" were discussed and specific challenges created. Once the challenges were identified, teachers took part in "mash-ups." During a "mash-up" three teachers from different content areas identified academic standards for their respective background areas and assigned them to three "buckets" based on their connection to the design challenge. One "bucket" was labeled as *critical for designing a solution to the challenge*, another was labeled as *contextually relevant to the challenge but not critical for a solution*, and the last was titled as *not relevant to the challenge*. In this way the teachers identified the approach to presenting the academic standards to the students in the upcoming project cycle. Following this exercise, teachers created mini design-based workshops to address the non-relevant topics as well as dojos focused on the contextually relevant standards identified. This approach allowed teachers to track student learning within the project challenges, the mini design-based workshops, and the dojos. The overall sentiment among participants was positive toward the authentic learning environments and the student's opportunity to engage in "real-world" problems. Further, there was value noted in the unique approach designed by the faculty (mash-ups) to identify the academic standards to be covered in each challenge – this approach may be useful in other schools and scenarios to address a variety of standards through complex real-world problems.

Open-Ended Learning

While the participants often noted the benefits of open-ended learning opportunities for student creativity and growth, they also shared that they struggled with this learning environment. Specifically, faculty noted difficulty in the preparation of materials for study as well as developing a means to assess learning and student progress through the requirements for successful transition into post-secondary education. The high demands on faculty associated with the highly open-ended environment were noted by several faculty and faculty attrition was noted as an area of concern in interviews. Although the benefits of highly open-ended learning environments included creativity and personalization by students, the toll on teachers was significant – identifying approaches to alleviate these pressures or assist in these challenges appears to be necessary for widespread adoption of this approach.

Competencies Not Measured Through Standardized Assessments

The participants noted the continuous struggle between teaching in authentic contexts to develop the skills necessary for student agility in the future workforce and measuring learning through state-level standardized assessments. Faculty discussed the disparity between actual competencies needed to complete specific tasks and the items measured on the state's standardized tests. Overall, the participants suggested a belief that the student skills being developed in the IHS model were more aligned with the necessary competencies for future success than those measured on standardized tests—this was a point of pride for many participants and a rationale for many, if not most, of the decisions and approaches in the school's curriculum

Teacher Burn Out

Multiple participants compared their first year at the IHS to "building an airplane while flying it." Most of the participants spoke positively of the school, the approach, and the year in review, but almost all also noted high levels of stress and some frustration with the evolving school model. While the majority of the teachers and staff were retained following the first school year, a few teachers did note in the interview that they opted not to renew their contracts for the following year because of their feeling of "burn out." Relatedly, the unique model of this school requires teachers who are skilled in their content area but also capable and willing to work in a flexible, adaptive environment with their peers. As this is not traditionally the way in which teachers are trained, the innovative school model shrinks the talent pool from which to hire teachers. So, in order to challenge traditional school models at a larger scale, the results would indicate that the country needs to continue to address the challenges with the teacher shortage.

System and Facility Challenges

One of the major challenges highlighted by the administrative staff was that the available technology solutions, such as learning management systems and assessment platforms, that work in traditional schools did not fit with the school's model for competency-based personalized learning. Most of the systems available, assume that a school has a defined master schedule with discrete subject-specific classes. However, one of the novel approaches to the school model was to eliminate a master schedule and allow flexible grading to promote mastery of the identified competencies or big ideas throughout open-ended learning in the design challenge cycles. Traditional school grading is typically fixed based on the time in which students complete a class. But, when individual classes are removed and students and teachers schedule the learning experiences based on the design challenge, current educational technology systems appear to be useless. Therefore, innovative schools must create systems to support such learning environments catering toward their unique designs and needs.

Another challenge noted by the participant administrators is finding adequate facilities to create and foster the type of learning environment that the school is implementing. With the limited funding available to schools, establishing authentic facilities for active learning, ones that mimic real-work environments, (e.g., working on solutions to industry-sponsored challenges) remains difficult. Therefore, it may be advantageous to leverage networks and connections both the school and partnering university have with various industries through the design challenge cycles to ensure students have the resources to develop innovative solutions and learn in engaging/authentic environments.

EARLY RETURNS

Following the data collection, the school provided some promising notes on the early returns of the school. First, the students in the first year completed the PSAT 9 (Preliminary Scholastic Aptitude test for 9th grade; a national standardized test administer by the College Board). The results showed that 52% of the freshman students met the College Board's college ready benchmark as compared to the national benchmark of 40%. More specifically, all of the school's subgroups outscored their national counterparts and 85% of the freshmen were retained at the end of the school year as well as 90% of the faculty and staff. Lastly, all of the industry partners continued to be engaged to support the design challenge cycles and an additional eight partners were added. The IHS has also established plans to open another school in another urban community and to help build the capacity for others across the country to try to do similar innovative school approaches.

CONCLUSION

With an explicit goal to "reinvent high school," the IHS has developed unique approaches and partnerships to provide a different educational experience for both students and teachers. Participant responses suggested both excitement and concern related to both the instructional design approach designed and implemented at the IHS and the intentionally integrated approach of the content at the school. While many participants noted the unique opportunities the IHS afforded others, they also noted some ambiguity around the effectiveness of the approach for student learning outcomes. Challenges, for both teachers and students, which resulted from the innovative approach—and all that came with it—were also discussed by many of the participants. Authentic PBL and DBL experiences are used as students work in small teams—with even smaller teams of teachers—to solve real-world challenges formed in conjunction with industry partners. These new experiences present students with opportunities to work closely with teachers, experience open-ended learning, and engage in competency-based personalized education.

From analyzing the data collected in the study, several themes emerged in regards to the experiences of teachers and administrative staff when striving to reinvent the high school learning experience. The themes, which included (1) developing novel approaches for planning and implementing design-based learning cycles, (2) facing challenges with personalizing learning, (3) establishing methods for creating authentic and industry-driven learning experiences, (4) addressing challenges with open-ended learning, (5) confronting concerns about competencies that are not measured through standardized assessments, (6) struggling with teacher burnout, and (7) challenging traditional school systems and facilities with integrated learning environments, each offered discussion points toward potential implications, considerations, and future directions for the implementation of innovative design-based educational approaches. For example, the results highlight opportunities for the following:

- Developing new educational technologies capable of supporting innovative learning environments and achieving competency-based personalized learning.
- Establishing best practices for school-industry partnerships for the creation of authentic learning facilities.
- Providing pre-service teachers with experiences teaching in non-traditional school environments.
- Investigating radical approaches toward addressing the national teacher shortage.
- Revisiting the competencies measured through standardized assessments and their alignment with the future of work and learning.
- Taking caution when implementing highly open-ended learning environment that use design-based learning strategies to ensure that it is appropriate for the learners and for the development of expertise.
- Continuing the examination of the IHS instructional techniques, such as the PL3 and Mash-Up approaches, to better understand how they can be leveraged to help others promote effective learning through integrated STEM and design-based pedagogies.
- Leveraging the IHS school model when creating new innovative schools to help mitigate teacher burnout.

Each of these opportunities also comes with a challenge as teachers reported concern over the “actual learning” happening in relation to standardized assessments and the high levels of teacher burnout occurring as a result of the pressures placed on them. As the IHS moves forward, it may be important to continue studying the lived experiences of both the faculty and the students in this unique setting. Understanding the benefits and challenges may facilitate new and improved approaches and modifications which could lead to their goal of “reinventing” high school.

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