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ARTICLE

STEM High School Teachers' Views of Implementing PBL: An Investigation Using Anecdote Circles

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Abstract

Problem-based learning (PBL) has been gaining in popularity, especially within the context of STEM-based (science, technology, engineering, and mathematics) schools. Program assessments for these schools typically focus on student standardized test scores rather than the needs of the teachers. This study utilized anecdote circles, storytelling via moderated group discussions, to investigate teachers' needs related to developing and implementing authentic, interdisciplinary PBL activities in an urban, public STEM high school. Teacher experiences and viewpoints were explored within three broad themes: assessment; coaching and training; and authentic learning. The analyses provide insights for transitioning a school for effective PBL implementation as well as improving teaching and learning best practices. Recommendations to improve PBL practice based on the study's results are also included.

Keywords: anecdote circles, problem-based learning, faculty development, professional development, STEM, needs assessment

Introduction

Problem-based learning (PBL), with a successful history especially within medical education, has not been widely adopted by K–12 institutions (Hmelo-Silver, 2004). The exception has been STEM-based (science, technology, engineering, and mathematics) schools, which frequently adopt either project-based or problem-based learning as a pedagogical model perhaps because of its fit with teaching engineering applications (Meyrick, 2011). PBL program assessments typically focus on comparing PBL students to traditional students using standardized tests, especially in medicine (Strobel & Barneveld, 2009), rather than the needs of the teachers who are implementing the PBL activities. Yet it is important to assess different stakeholder groups to ascertain their needs and, therefore, better address improving the program's effectiveness (McNeil, Newman, & Steinhauser, 2005). The purpose of this study was to use anecdote circles, storytelling via moderated group discussions, to investigate teachers' views related to developing and implementing effective, authentic, interdisciplinary PBL activities in an urban, public STEM high school in the American Midwest. Anecdote circles were chosen for this study because they allow researchers to explore themes related to a situation while providing representational stories about an organization through the lived experiences of the participants (O'Toole, Talbot, & Fidock, 2008).

Anecdote circles are lightly moderated group discussions that rely on a form of storytelling and story listening focused on the exploration of specific themes using prompts to initiate conversation among the participants that can be used to inform practice (O'Toole et al., 2008) or initiate organizational change (O'Toole et al., 2008; Ramaswamy, Storer, & Van Zeyl, 2005). During the study, the STEM high school (STEM HS) was in its first year of operation with only first-year (ninth grade) students enrolled. The creation of the STEM HS represented the continuation of a district-wide focus on PBL-based STEM schools. An associated STEM middle school (STEM MS) was already successfully using PBL with fifth through eighth grade students. Most of the STEM HS teachers were new to PBL and all were new to the high school. In this study the focus of the anecdote circles was to investigate problems the STEM HS teachers had in developing and implementing authentic and interdisciplinary/multidisciplinary PBL activities. A description of the STEM HS is provided in the next section in order to inform the study's findings.

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The STEM High School

The STEM HS began operation in August of 2012 with its first freshman class. At the STEM HS and the associated STEM MS, teachers are referred to as learning coaches or coaches (a teacher would be called Coach Smith, for instance, rather than Mrs. Smith). Similarly, students are referred to as learners. The use of these terms represents a school-wide approach to change the culture of these two STEM schools. We preserve these terms throughout this paper when specifically referring to the teachers and students at the STEM HS and STEM MS.

This study occurred during the inaugural year with ninth grade STEM HS learning coaches. Grades 10–12 had not yet been implemented. Instead, each year the STEM HS expanded by an additional grade with the admission of a new freshman class until there were four grades, ninth through twelfth grade. All of the STEM HS courses are taught as honors courses. In ninth grade all students took the following: biology, English, Chinese, geometry, engineering, physical education, and world history. The STEM HS curriculum, like that of the STEM MS, uses PBL and other research-based teaching methods. During the summer of 2012, all learning coaches received a week of PBL professional development from the Illinois Mathematics and Science Academy (IMSA), an outside group that specializes in PBL education.

The STEM HS, like the STEM MS, was developed within a partnership that includes a local university, a chamber of commerce, the public school district, and the city within which the STEM HS resides. The aim of this STEM partnership is to develop an integrated curriculum that meets state K–12 standards, represents collaboration among the various stakeholders, and uses active learning best practices that help prepare students for college degrees and careers related to STEM. In addition, the STEM partnership, part of the Akron Ohio STEM Learning Network (Akron-OSLN) has contacts throughout the region and state that can provide additional collaborative opportunities through the larger, state-wide OSLN. OSLN facilitated gaining access to other STEM schools in Ohio, including information about their use of problem-based learning or project-based learning for benchmarking during the development of the STEM HS. The university provided a liaison to the STEM HS for two years: the year of developing curriculum and its first year of operation. The liaison, a faculty member, facilitated the use of university resources, assisted with the curriculum design, and provided professional development opportunities. This liaison also provided leadership during the year prior to the opening of the STEM HS, including curriculum development and curriculum mapping within the PBL framework. The liaison also assisted with the STEM MS, primarily related to locating discipline experts from the university to interact with STEM MS students during their PBL activities.

The STEM MS, not part of this study, was implemented four years prior to the opening of the STEM HS. The STEM HS was the natural progression following four successful years of the STEM MS and was part of the original plan created before the first class entered the STEM MS. The STEM MS was consistently rated excellent by Ohio as part of that state's annual school evaluation process. In addition, the STEM MS was part of a study within OSLN examining all of the STEM schools within their network. As part of that study, University of Chicago evaluators indicated that the learner and coach reactions to the STEM MS experience were positive, with high levels of motivation and student perceptions of engagement (LaForce & Rand, 2012). The perception was that the STEM MS learning coaches and leadership would provide an important resource for the STEM HS. STEM MS coaches received professional development for PBL from the IMSA, as did the STEM HS coaches although in a lesser amount. Grant monies allowed each new year of coaches at the STEM MS to experience PBL professional development on the order of two weeks during the summer with touchpoints during the remainder of that first academic year (like the STEM HS, the STEM MS added one grade per year until the grades were fifth through eighth).

Originally, the plan for the STEM HS was to provide similar professional development for their coaches. Unfortunately, the lack of grant funding and district monies reduced the professional development for the STEM HS learning coaches. Instead, the introduction of PBL to 30 new learners entering the STEM HS (who did not attend the STEM MS) was combined with the professional development of the incoming ninth grade coaches over the course of four days with learner presentations consuming the fourth day. In other words, the STEM HS coaches were introduced to PBL and then implemented a PBL exercise with the new learners within a framework considerably shorter than that experienced by their STEM MS counterparts.

Other differences included the construction of a new building for the STEM MS opposed to the adaptation of an existing, older high school building for the STEM HS. In addition, STEM MS teachers are licensed to teach in multiple disciplines (e.g., a teacher may teach both English and social studies) whereas STEM HS teachers specialize in a singular discipline (e.g., English or chemistry). These differences between professional development, discipline specificity, and building perception may have impacted the STEM HS teachers' success with their PBL activities, especially in comparison to their STEM MS colleagues. Disciplinary differences may have affected learning coaches' ability to plan PBL exercises as interdisciplinary, and this idea was included within the investigation. It is important to note that approximately 70 of the graduating eighth grade students from the STEM MS enrolled within the inaugural class of 100 STEM HS ninth

graders. These STEM MS learners had four years of positive PBL experiences, whereas the new STEM HS learners only had their summer PBL experience with the new STEM HS coaches going into their ninth grade year at the STEM HS.

Authentic STEM-based PBL Experiences at the STEM HS

Within the context of the STEM MS and HS, problem-based learning is used as a pedagogical strategy as well as a tutorial process that encourages student-directed learning focused around solving a meaningful, open-ended, real-world problem with no set solution, as described by Hmelo-Silver (2004). Certainly PBL has been adopted widely in whole or as part of a hybridized approach in medical education, but is also used in other disciplines such as teacher education and at other educational levels such as K–12 (An, 2013; Barrows, 1996). The professional development received by the STEM HS learning coaches focused on PBL as a combination of curriculum organization and instructional strategy to produce a "minds-on, hands-on" learning experience by engaging students as stakeholders, and was conducted by the IMSA. It emphasized that the PBL experiences should organize learning in a relevant and connected way, as suggested by Torp and Sage (2002; 1998) that allows for the facilitation of deeper learning and the social construction of knowledge as described by Vygotsky (1986). This is accomplished by having students work collaboratively in small groups to determine what must be learned and how to apply that learning as a solution.

Like the original PBL method implemented at McMaster University, as detailed by Barrows (1996), the STEM HS learning coaches were taught that the PBL experiences they would develop and implement should exhibit the following six characteristics:

> learning is student-centered; learning occurs in small student groups; teachers are facilitators; problems form the organizing focus and stimulus for learning; problems are a vehicle for the development problem-solving skills; new information is acquired through self-directed learning. (p. 5–6)

However, even with exemplary professional development, barriers exist when implementing school-wide PBL. To overcome such barriers, the school needs to instill a complex blend of "motivation, skill, positive learning, organisational [sic] conditions and culture, and infrastructure of support" (Stoll, Bolam, McMahon, Wallace & Thomas, 2006, p. 221). Stoll and colleagues suggest that professional learning communities can help build capacity for dealing with these barriers. Yet, although the STEM HS coaches were members of a professional learning community, the barriers to authentic PBL development and implementation were not eradicated.

Barriers to Using PBL

A change in the teacher's role from that of traditional transmissive educator (sage on the stage) to facilitator and tutor (guide on the side) is critical in effective PBL (Ertmer & Simons, 2006; Hmelo-Silver, 2004). PBL requires new roles that are unfamiliar for teachers as well as students (Ertmer & Simons, 2006). In this new role, the STEM learning coaches needed to model learning and inquiry behaviors, as well as coach students to think independently through metacognitive questions such as: What is going on here? What else do we need to know? What have we been doing effectively while working on this problem? (Stepien & Gallagher, 1993). The learning coaches not only need to guide students through the learning process, but also conduct "a thorough debriefing at the conclusion of the learning experience" (Savery, 2006, p. 12), a critical component of the PBL process that helps further instill metacognitive skills and self-directed learning strategies in the learners. Such debriefings or reflections are a key component of the PBL process, helping students to "(a) relate their new knowledge to their prior understanding, (b) mindfully abstract knowledge, and (c) understand how their learning and problem-solving strategies might be reapplied" (Hmelo-Silver, 2004, p. 247). Thus, the STEM HS learning coaches are to encourage both the construction of knowledge as well as the development of lifelong learning skills and strategies for students. Their use of PBL should encourage flexibility in critical thinking and meta-awareness of one's own process of learning while making students responsible for their own learning (Hmelo-Silver, 2004). Such a transformation in teaching and learning practice can be problematic, even for those receiving effective professional development. The STEM HS learning coaches' professional development was provided by a well-respected, outside organization known for providing instruction on designing and implementing PBL nationally (IMSA). This same organization provided professional development opportunities for the coaches in the STEM MS before each inaugural year. However, due to budget constraints and timing, the professional development experiences were not equivalent, with the STEM HS coaches receiving substantially less professional development prior to the start of the school year as well as throughout the inaugural year of operation. The STEM HS coaches may have experienced additional barriers in developing and implementing PBL, and the literature speaks to other barriers to adopting and implementing PBL.

In their review of the literature, Ertmer and Simons (2006) found that some barriers to adoption of PBL included teachers' concerns with the amount of time it takes to plan PBL experiences, difficulty in encouraging students to take a more active learning role, and issues with assessment of PBL

activities. The findings presented here are consistent with Ertmer and Simons' (2006) review, particularly with concerns about assessment. An (2013) noted that the "challenges teachers face when designing PBL are less understood" (p. 65), and her study addressed some of the professional development needs for teachers struggling specifically in the area of problem design. The research presented here also finds that the creation of effective problems is a crucial continuing professional development need of the teachers who participated in this study. As An (2013) recommended,

> professional development programs should provide PBL novices with (a) an opportunity to design the whole PBL process using a systematic approach, (b) synchronous, interactive questioning sessions and customized scaffolding, (c) concise and easy-to-understand guidelines and checklists, and (d) opportunities to have a successful experience with PBL design. (p. 72–73)

Situational aspects, beyond professional development, also impact PBL implementation. Grant and Hill (2006), for example, described five factors that interact to impact the transition from teacher- to student-centered pedagogies, including

> 1) recognition and acceptance of new roles and responsibilities, 2) comfort level . . . with physical dislocations inherent to student-centered pedagogy, 3) tolerance for ambiguity and flexibility in management . . . of student-centered learning, 4) confidence in integrating technology . . . into teaching and learning, and 5) integration of new pedagogy with realities beyond the classroom, . . . situated within a larger context of the school, district, state and national cultures. (p. 23)

Boyer-Stephens and Miller (2000) presented a case study where PBL was used as the strategy to teach PBL to high school career/technical education instructors in an intensive in-service program. Boyer-Stephens and Miller's program concentrated on problem development and curricular integration, core areas identified as needing additional support in the research presented here. Their case study also included built-in follow-up sessions with the instructors during the school year, an opportunity for additional reflection that emerged as a recommendation in this research as well. The follow-up session included time with the original facilitator and gave the instructors the opportunity to request additional training in targeted areas, for example, in improving the debriefing or reflection portion of the PBL experience. This is similar to the need identified in this research for additional training in assessment techniques, some of which can take place during the PBL debrief.

With respect to K–12 education specifically, however, only minimal research is available on difficulties encountered by teachers who are implementing PBL (Brush & Saye, 2000; Ertmer & Simons, 2006). While there is a moderate amount of research addressing the use of PBL as a strategy for training teachers, in-service teachers, and education students in the use of PBL (An, 2013), there is almost no research addressing teachers' ongoing professional development needs after they have been initially trained and have implemented at least one PBL (Brush & Saye, 2000). Certainly this lack of research impeded stakeholders' ability to address PBL implementation issues at the STEM HS and was an incentive for this study.

Prior to implementing this study, the researchers were aware that the STEM HS coaches encountered numerous barriers to implementing effective PBL experiences for learners, such as struggling to find authentic problems connected to the curriculum, creating multidiscipline integration into problems, drawing on the expertise within the partnership including the university, and determining how to assess various aspects of the PBL activities. STEM HS leadership sought to discover more about coaches' specific experiences with developing and implementing PBL as well as to identify best practices and areas for further improvement and professional development. The researchers also sought to align this research with the state standards for educators in terms of self- and program-assessment for the purposes of improving teaching, learning, and professional development. Anecdote circles were deemed a means to provide the necessary information as well as meet those state standards.

Method

Anecdote circles are lightly moderated group discussions intended to elicit examples of lived experiences. Anecdote circles differ from focus groups in that they are not intended to answer a specific question or test a hypothesis. Additionally, this method is not used to gather participants' thoughts and feelings. Instead, anecdote circles allow exploration of themes loosely directed through the use of question prompts delivered by a facilitator. As described by O'Toole and colleagues (2008), "anecdote circles can usefully act as a way to capture representational stories about an organisation [sic], and act as a vehicle for the design of intervention strategies for beneficial organisational [sic] change" (pp. 28–29). Anecdotes rather than complete stories are encouraged, as they are specific examples of lived or observed behaviors or situations. Prompting a participant for an anecdote rather than a story helps keep the examples short and to the point. Participants, if asked to provide a story, may feel the need to provide a carefully crafted narrative with a beginning, middle, and end. While they are not structured to answer a specific question or test a hypothesis, anecdote circles do have a particular direction that is determined by the themes the study is intended to explore. Anecdote circles are used in organizations to

overcome the limitations of interviews and surveys, especially when trying to evaluate project successes and shortfalls that may otherwise be difficult to measure (see, for example, Callahan, Rixon, & Shenk, 2006). They are also sometimes used to facilitate organizational change (O'Toole et al., 2008; Ramaswamy et al., 2005). In this study, anecdote circles were used to gather data in the form of specific examples of learning coaches' experiences as described by the learning coaches.

Themes for Exploration

The first step in the anecdote circle process it to identify broad themes for exploration. The primary researcher, a program specialist (shared between the two STEM schools), and a STEM HS learning coach identified themes by brainstorming, grouping, and then categorizing a list of issues specific to the STEM HS PBL experience. The program specialist was involved in training other schools in PBL implementation (through the Akron-OSLN). Her range of experience was especially helpful in generating the themes. Based on the brainstorming and categorization process undertaken by the project team, the following three themes emerged for further exploration: assessment; coaching and training; and authentic learning.

Prompting Questions

Within each theme the team prepared two or three prompting questions designed to elicit relevant anecdotes from the participants. Using a method proposed by Callahan and colleagues (2006), a process for building effective question prompts using three specific components was followed. This process uses an image-building phrase, followed by additional information to enhance the image, and then an open-ended question that uses emotive words. Image-building phrases begin with words such as "Think about . . ." and "Imagine . . ." and prime participants to picture a specific situation in their minds. Additional information is then added to enhance the image, which helps the participants as they search their prior experiences for an example. Emotive words are then used to represent a range of emotions—the emotional spectrum, as Callahan and colleagues called it (2006, p. 11)—so as not to influence the direction of the participant's answer. For example, one of the prompts used in this study was structured as follows:

- Image-building phrase: Think about how multiple forms of assessment opportunities for mastery are available within a PBL unit.
- Additional information to enhance the image: This can be within your individual unit or the overall PBL experience.
- Emotional range: When have you been really satisfied or actually worried about assessment results of a PBL unit?

Finally, "when" and "where" questions are used most often as they are more likely to elicit anecdotes, whereas "how" and "why" questions are more likely to yield opinions. The prompts developed by the project team and used during the anecdote circle sessions are listed in Appendix A.

Data Collection

All learning coaches (seven full time at the STEM HS and two shared between buildings) as well as the program specialist were invited to participate in the anecdote circles. Generally speaking, anecdote circles are comprised of 4–12 peers who share a common experience and a facilitator. In this study two separate anecdote circles, one morning and one afternoon session, were held during regularly scheduled planning periods in order to provide an opportunity for all learning coaches to participate. Three STEM HS learning coaches and the program specialist participated in the morning session and four learning coaches participated in the afternoon session for a total of eight participants and 100% of the full-time teaching staff of the STEM HS. The participants spent approximately 60 minutes actively engaged in their anecdote circles with one of the authors as facilitator during both sessions. Sessions were recorded to facilitate transcription.

Themes for the anecdote prompts used during the anecdote circles were prioritized in the following order: assessment; coaching and training; and authentic learning. Within each theme two or three prompts were listed, also in priority order (see Appendix A). To ensure at least minimum coverage of all of the themes, the top prompt from each theme was covered first. The morning circle covered the top three prompts. The afternoon circle was able to cover the top three prompts as well as one additional prompt from within the coaching and training theme, as that prompt followed naturally as part of the discussion. In both circles the facilitator asked for more specific examples when necessary and asked clarifying questions throughout. When the conversation digressed into opinion the facilitator directed its focus back to the sharing of specific examples. Although the circles focused on gathering data in the form of concrete examples, some discussions included opinions and theories about why experiences were positive or negative. Anecdotes, general comments, longer stories, and opinions related by the learning coaches during the anecdote circles were all considered in the final analysis of the data.

Data Analysis

The two hours of recorded anecdote sessions were professionally transcribed and then coded. In general, codes are collected into categories, and from categories themes can emerge (Saldaña, 2013, p. 13). The coding in this study was a blend of provisional and exploratory coding, and focused

on similarities in anecdotes across participants and across sessions, for challenges and solutions, and for observations about aspects of the PBLs that did or did not work well.

Provisional coding, according to Saldaña, relies on a list of codes generated by the researcher based on what their "preparatory investigation suggests might appear in the data" prior to collection and analysis (2013, p. 266). This study was expected to yield examples of best practices, challenges, solutions, and areas for further development. Provisional codes chosen were: "best practice," "challenge," "solution," and "development needed."

Exploratory coding, on the other hand, is open-ended, and is often the preliminary assignment of codes based on the collected data (Saldaña, 2013, p. 263). Examining the transcripts and applying codes yielded descriptions strikingly similar to the provisional codes. These exploratory codes yielded three very broad umbrella categories: strategies; challenges; and positive examples. The anecdotes initially coded as "positive examples" were ultimately reframed and rolled into the "strategies" category.

Results and Discussion

The umbrella categories that emerged from the coding (i.e., challenges and strategies) were relevant across all three of the original themes (assessment; coaching and training; and authentic learning). The provisional and exploratory codes were ultimately rolled into two large categories: "challenges" and "strategies." Within this section the results and discussion are grouped into two main findings (areas requiring attention and the need to improve the use of the STEM partnership) that emerged across the three themes. Tables in each of those subsections provide challenges and strategies that address these themes in this area. Paraphrased anecdotes are used within these tables to give a better sense of the lived experiences of the STEM HS learning coaches related to PBL. A final subsection addresses additional findings associated with professional development opportunities.

Finding 1: Areas Requiring Attention

The challenge of designing and effectively completing a school-wide (i.e., interdisciplinary/multidisciplinary) PBL was clearly evident across all three themes. Additional training and strategies for improving interdisciplinary/multidisciplinary PBLs thus emerged as the top recommended area for development within the STEM HS program. Most specifically, the following areas required attention:

- The ability to integrate and assess content standards within and across an interdisciplinary/multidisciplinary, school-wide PBL.
- The ability to design authentic PBL experiences where the experiences are not overly contrived (or contrived at all) and where natural connections can be made across disciplines.
- The offering of professional development that includes more cross-disciplinary and interdisciplinary training that includes strategies for designing collaborative interdisciplinary/multidisciplinary PBL.
- The differentiation of the needs of the STEM HS coaches relative to those of the STEM MS coaches, which includes understanding that STEM HS coaches are licensed in one discipline and STEM MS coaches are licensed in two or more disciplines.

With respect to multidisciplinary PBL experience development, it appears that the learning coaches may not be sufficiently engaged as a collective—or collaborating enough—when creating the experience. Professional development that addresses communication, brainstorming, and planning a PBL that includes working together to list the relevant content standards, integrated subproblems, and presentation of solutions should help coaches overcome the challenge of integrating and assessing content standards within a whole-school PBL.

Overall, the learning coaches expressed a need to find ways to make the connections between and across subjects more apparent as part of a collaborative PBL planning process. This includes the integration and assessment of specific content standards as part of the cooperative thinking and development process. Learning coaches' experiences illustrating the challenges they face and strategies based on their successes are paraphrased in Table 1 (next page).

Finding 2: The Need to Improve the Use of the STEM Partnership

Involvement with outside experts and agencies appeared across all three themes as important in different ways and for different reasons, and thus an increase in interactions with external partners is the second recommendation indicated by this research. This actually refers to both interactions for the coaches, especially in the area of professional development, as well as with subject experts to help provide more robust and authentic PBL experiences for the learners.

External experts are valued for both their subject knowledge as well as the additional motivation they provide for the students. They are helpful in training learning coaches, and they can expand the possibilities for problems and solutions within a PBL experience. Most specifically, the following kinds of interactions with external individuals and institutions are identified as so beneficial that they should be pursued whenever possible:

- Meaningful public feedback and interaction for learners, since the impact is often greater than feedback from coaches and other school personnel.

Table 1. Indicators that additional training for multidisciplinary PBLs is warranted.

Topic Area	Challenges	Strategies
Assessment	Difficulty assessing on content standard when PBL is whole-school; Assessing things that don't fit neatly into content standards; Matching learners' accomplishments to content standards; Difficulty integrating specific subjects into PBL; Easier to see 21st Century Skills than content standard knowledge, but don't want to assess only that; Difficult to find the one or two content standards that can be assessed during the whole school PBL and not just the 21st century skills; Hard to determine who will assess what aspects of the PBL.	Outside experts brought new ideas and new ways of thinking to the table; Outside experts helped coaches and learners think differently; Outside experts broadened the understanding and knowledge of possible solutions; Observing learners' apply what was learned in the PBL to their own lives, taking the process home to their family; Assess individuals throughout the course of the exercise and assess group as part of presentation of learning.
Coaching and Training	Need more information about what cross-curricular PBLs look like and how they work over time; Not enough training for cross-curricular PBLs.	PBL training with subject experts works well but also illustrates the need for more multidisciplinary training; Rotate learner groups among the coaches (keeping a group with one coach doesn't give them enough exposure to the other coaches' expertise).
Authentic Learning	Making content meaningful and relevant; Difficult getting content standards to fit into the PBL; Timing is important, and challenging, since learners need to have appropriate content skills when called upon to use them in the PBL; Finding equilibrium between informational and concrete problems when designing PBL; High School has more specific content than middle school and coaches are a bit more independent; The more people a PBL tries to involve the more contrived and unconvincing it becomes; A weak or contrived connection between subjects in a multidisciplinary PBL can weaken the whole problem. A weak or contrived connection between subjects in a multidisciplinary PBL can weaken the whole problem.	Craft PBL to be concrete, with concrete outcomes; Experts provide such good information at the end of the PBL it would be helpful to have them provide input sprinkled throughout the project or process; Outside experts are helpful in making possibilities understood by both learners and coaches (e.g., possible solutions, possible techniques, possible strategies); Outside experts widen the possible outcomes.

Table 2. Indicators that interactions with external partners should be as fully utilized as possible.

Topic Area	Challenges	Strategies
Assessment	Public feedback (i.e., feedback from outside the group) is good for learners even if it's not always great for grading.	When speaking with outsiders it's good when learners can speak about what they know, but equally as good when they are able to indicate and acknowledge when they don't know; Public feedback has impact since it is coming from someone other than the coaches; Motivation of learners is increased, especially when they disagree with the professional committee; Students were motivated to show the outside committee wrong; Outside experts: brought new ideas and new ways of thinking to the table; helped coaches and learners think differently; broadened the understanding and knowledge of possible solutions.
Coaching and Training	PBL training for coaches with subject experts works well but also illustrates the need for more multidisciplinary training; Can training show examples of learners' solutions in action in their communities? And can the training show whom the players were who were able to make that happen? Can training help the school and the coaches learn how to motivate outside people to participate in the presentation of learning and actually use learners' results, or at least give them [validating] feedback? How learners' solutions are, or can be, used or applied in the real world is important.	PBL training for coaches with subject experts; Training with outside experts that includes reflection with the outside experts on what can improve or needs to be changed day-to-day throughout the training exercise; Three reflective questions at the end of each day of training, with a moderator who uses those reflections to provide feedback the following day; Outside experts are useful as motivators for the learners; Anticipation of outside feedback motivates learners to perform well; For external experts to want to take the learners' solutions and actually use them is important validation for the learners; Learners want more than just the presentation of learning; they want to see their solutions used in the real world.

Table 2, cont'd. Indicators that interactions with external partners should be as fully utilized as possible.

Topic Area	Challenges	Strategies
Authentic Learning	Learners need to see how their solutions impact the real world; The exercises/school needs to find a way to allow learners to see how their solutions work in practice; If PBLs come in from the outside they can be good, but then there isn't too much control over timing in terms of the learners' skills; Experts provide such good information at the end of the PBL that it would be helpful to have them provide input sprinkled throughout the project/process.	Learners out in the field, helping university researchers gather data; Learners connect what they learned in the classroom to what they were doing out in the field; Learners making educational tools for use at a museum; When bringing in experts, remind them of the coaching role and encourage them to answer questions with questions; Outside experts are helpful in making possibilities understood by both learners and coaches (e.g., possible solutions, possible techniques, possible strategies) and widen the possible outcomes; Outside experts motivate learners though hands-on exercises.

- Externally facilitated, reflective PBL training for the learning coaches.
- Visible application of learners' work in the real world, through actual implementation of their solutions or as hand-on activities helping experts.
- Partnerships with more outside institutions to provide a consistent pipeline for possible experiences or projects for learners.

Table 2 paraphrases and condenses indicators from the coaches' anecdotes that illustrate several of the challenges and strategies across all three themes that lead to the recommendation that interactions with external partners should be increased when possible and/or feasible.

More interaction with external partners was identified as necessary and beneficial for both learners and learning coaches in developing and implementing PBL experiences. For learning coaches it means taking advantage of more professional development opportunities offered or facilitated by individuals or organizations outside of the high school itself. The training with an outside facilitator who used learning coaches' reflections to help them improve their own understanding of PBL development was provided as an example during an anecdote circle of a very effective professional development event. Additional facilitated professional development throughout the school year was also indicated as important. Some coaches felt they would have additional questions for trainers sometime after the initial training sessions, once they had tried some of what they had learned in their own classes or during a PBL experience. Increasing the frequency of professional development from existing partnerships may fill much of the need expressed by coaches in the anecdote circles. Strengthening existing partnerships with local universities and regional resources may yield more professional development opportunities and resources.

There are a variety of ways to make connections in the community. Simply tracking the various connections students, teachers, and administrators make over time and across projects by maintaining a database of subject experts, learning partners, and organizations for which the student can work or produce materials can help the school build the contacts and community capacity for ongoing relationships. Once positive and fulfilling relationships are established, the likelihood for PBL opportunities presented from outside the school increases. Capacity building such as this only happens over time, and the sooner a database tracking partnerships and collaborative successes with the community can be established the better.

Additional Findings

Three other areas emerged for further consideration as professional development opportunities: adding variety to rollouts, more—and more effective—use of reflective time and activities in groups as well as by individuals, and better preparation for working with groups of learners within the PBL exercises. These areas were discussed in the anecdote circles, but were not represented across all themes or were not widely discussed across both anecdote circles. Although these areas did not emerge as strongly as the two previously presented

recommendations, they are addressed briefly, including suggested strategies proposed in the anecdote circles. Each of these areas is also amply covered in the PBL and related literature such as An (2013), Brush and Saye (2000), and Savery (2006). Additionally, online PBL support sites should be easy to address by the learning coaches themselves. These resources could be used to develop in-house professional development activities for the learning coaches.

The notion of learning how to add variety to the rollout strategies in order to keep them fresh was indicated as important in both the coaching and training and authentic learning themes in one of the anecdote circles. Coaches were concerned that students may become bored when PBL exercises are introduced in a formulaic way too often. The question that arises here, and would require more exploration, is whether students who anticipate a PBL based on the rollout strategy will begin to view them as less authentic and more as just another school construct. One example related in a circle, and possibly useful as a school-wide strategy, is to introduce the PBL to smaller groups of learners rather than to the entire group together. The premise is that learners prefer the small group introductions and find them to be more meaningful because they are more personal. This is supported in the literature including Savery (2006) and Torp and Sage (1998).

Reflection and the usefulness of reflective activities on improving PBL experiences were noted several times within the coaching and training theme and across both anecdote circles. Reflective activities during professional development, particularly at the end of training days when interpreted and used by a facilitator to help coaches improve was described as especially helpful. Self-reflection and reflective conversations with other coaches during down times when learners aren't present was highlighted in anecdotes as also being beneficial. Interestingly, the use of student reflections, such as student reflective journals and class conversations, was provided as an additional example strategy for improving PBL effectiveness.

Better understanding and preparation for working with students in groups, such as strategies for assigning learners to groups and for keeping groups motivated was mentioned in one anecdote circle in conjunction with discussion of other aspects of PBL. For example, assessing the work of individuals as members of a group, and of the group's work as a whole, often represents a challenge. One strategy that was shared for assessment includes having groups and individuals be very explicit when collectively providing the proof behind their thinking.

Conclusion

Anecdote circles proved to be an effective method for gathering stories from learning coaches that provided specific examples of their experiences in implementing PBL in the STEM HS. Two areas for consideration and possible improvement emerged from the data collected in the anecdote circles: training and strategies for improving multidisciplinary PBL experiences; and increasing interactions with external partners. With respect to interdisciplinary PBL experience development, learning coaches need to increase their level of collaboration when creating the PBL experience and work to overcome the challenge of integrating and assessing content standards within a whole-school PBL. Based on a recommendation from An (2013) for PBL novices, perhaps the whole-school PBL design should take a more systematic, scaffolded approach. If after trying a more collaborative, collective development approach the whole-school PBLs still seem too contrived or short on content standards, the school should practice building capacity in PBL design skills by focusing on successfully integrating PBLs across two or three subject areas before attempting a whole-school PBL. This recommendation is also in alignment with An's (2013) findings that novice PBL designers should have opportunities to have successful experiences. Integrating across a smaller number of subjects, in varying combinations, may provide practice and build confidence in designing and deploying robust, authentic, multidisciplinary PBLs.

The second area of focus is the interaction with external partners. This actually refers to both interactions for the coaches, especially in the area of professional development, as well as with subject experts to help provide more robust and authentic PBL experiences for the learners. For professional development, simply increasing the frequency of the current training opportunities may fill the need expressed in the anecdote circles. More development with the regional organizations and similar in-state resources may also prove effective.

Fostering more collaboration with community partners for participation in PBLs will take time and some effort in recruiting individuals and organizations and nurturing those relationships. Being very intentional and specific when communicating needs to prospective expert consultants and mentors can help create a positive atmosphere and experience for them as well as the learners, and should help build the number of external resources willing to participate again and again. Maintaining a database of contacts and experts is essential so that the school and learning coaches have a pool of human resources to draw upon.

Beyond the two main recommendations for improvement and attention, three other areas emerged for further consideration: adding variety to rollouts, more use of reflective time and activities, and better preparation for working with groups. These have each been discussed briefly, including suggested strategies proposed in the anecdote circles.

In the environment examined in this research one of the primary tenets of the educational experiences relies on PBL

integration, particularly at the whole-school level. Adoption of PBL is thus a directive of the school program. That being said, findings in this research confirm especially that confidence in integrating resources and linking teaching to "realities beyond the classroom" (Ertmer & Simons, 2006; Grant & Hill, 2006) are critical factors and may require additional training, administrative support, and action beyond the initial professional development activities provided to the teachers and beyond the mandate of the school structure.

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Appendix A: Anecdote Circle Instrument (Themes and Prompts)

Anecdotes were solicited from the group through the use of specific prompts that have been crafted to explore particular themes. The themes addressed and the prompts used to elicit responses during the anecdote circle are included below.

Major Themes to Address:

- Assessment
- Coaching and training (professional development)
- Authentic learning

Anecdote Circle Prompts:

Theme: Assessment

- Think about how multiple forms of assessment opportunities for mastery are made available within a PBL unit. This can be within your individual unit or the overall PBL experience. When have you been really satisfied with or actually worried about assessment results of a PBL unit?
- Consider the opportunities in a PBL where 21st-century skills can be applied and demonstrated. Your experience with this could be here at the STEM High School or in a prior position. When have you been disappointed or pleasantly surprised with the way learners applied or demonstrated these skills?

Theme: Coaching and Training

- Recall that earlier this school year there were various professional development opportunities. You may have also participated in professional development elsewhere. When have you experienced a situation here at the STEM High School where you thought to yourself, "I could have used more training to get through this" or "My training in this area has helped considerably in this situation"?
- Think about ways in which the coaching culture here at the STEM High School is different from traditional classrooms. This experience is true for the coaches as well as the learners. Share an experience when you when you felt you were taking full advantage of a coaching opportunity and you were really enthusiastic, lukewarm, or even regretful about the outcome.
- Imagine a coaching experience through the eyes of a student. You have asked the learning coach a question and been answered with a question in return. Now, as a coach, describe an instance illustrating a learner's reaction to this kind of experience and your response.

Theme: Authentic Learning

- PBL units are designed specifically as vehicles for authentic learning. You may have also experienced authentic learning outside of a PBL exercise. When did you incorporate an authentic learning experience that you found surprising or frustrating in terms of how it affected your unit?
  - Alternative phrasing: PBL units are designed specifically as vehicles for authentic learning. You may have also experienced authentic learning outside of a PBL exercise. Give an example of an authentic learning experience that you weren't sure would work, and were either very happy or disappointed with the results.
- As part of the authentic learning experience, experts are involved in various capacities. Think about your interaction with experts as part of a PBL experience. When did you feel that your interaction with the expert had a powerful effect, positive or negative, on the learners' experiences?
- Think about the resources used in a PBL experience. Resources are used from the planning stages all the way through the presentation stage. Share a specific experience that illustrates your best or least effective experience with a resource.

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