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Andrew A. Tawfik, Jaclyn J. Gish-Lieberman, Jessica Gatewood (University of Memphis)
T. Logan Arrington (University of West Georgia)

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ABSTRACT

Teachers adapt their instructional strategies over time based on a variety of contextual constraints. In response to these challenges, teachers often have to make changes to their PBL approaches. While the literature has documented generally positive results of initial PBL implementations, less is known about the degree to which teachers adapt their usage of PBL over time. Some adaptations include a refined approach to teaching strategies, while others include significant diversions from the original PBL model. A better understanding of the changes teachers enact provides important insight as to fidelity and thus the expected learning outcomes of PBL. To address this gap, this research conducted semi-structured interviews with experienced K-12 educators who employed PBL over multiple years. In terms of preparing for PBL, themes that emerged from the interviews included more emphasis on reimagining the problem scope and design thinking. During classroom time, teachers described shifting perspectives in terms of the following: problem-solving skills over content knowledge, student control and teacher facilitation, and embracing failure. Relating to technology, teachers described more adoption trends towards collaborative tools, while also describing opportunities and challenges with digital literacy. Finally, teachers described strategic approaches to assessment in light of the ill-structured problems posed by PBL. Implications for practice and theory are discussed.

Keywords: problem-based learning; K-12; qualitative; design thinking

Introduction

Theorists assert that problem-solving is an important element of effective learning, especially given that many of the problems encountered within domain practice are ill-structured (Hara & Schwen, 2006; Jeong et al., 2019). These problems have no predefined solution; rather, an individual must generate a viable solution in light of the constraints, diverging perspectives, and criteria inherent within the context (Jonassen, 1997; Kim et al., 2017). Because there is no single solution within these ill-structured problems, practitioners must engage in causal reasoning (Hmelo-Silver et al., 2007), decision-making (Sabus & Macauley, 2016), and argumentation (Ju & Choi, 2017) as they collaboratively solve problems with their peers. Indeed, these competencies align with 21st century skills that emphasize the importance of critical thinking and inquiry needed to solve complex problems (van Laar et al., 2017).

Given the literature on how practitioners engage in problem-solving, theorists have discussed ways in which to better support these higher-order learning functions. This has caused many educators to move away from decontextualized and didactic forms of teaching towards adoption of problem-solving instructional strategies (Hung, 2016; Voet & De Wever, 2017). One of the most prominent strategies is problem-based learning (PBL), which asks students to solve a case that is similar to the types of problems that practitioners face (Barrows, 1986). In these strategies, students take ownership of their learning while instructors move towards a more facilitative role (Harper, 2018; Hmelo-Silver & Barrows, 2006; Kim et al., 2019). Learners especially engage in inquiry and self-directed learning as they construct their knowledge during various problem-solving processes (Frerejean et al., 2019; Monchaux et al., 2015). Furthermore, students work with their peers and resolve their diverging perspectives encountered during inquiry (Ertmer & Koehler, 2018;

Tawfik et al., 2018). It is therefore argued that this approach better prepares individuals for the types of problems encountered in domain practice (Kim et al., 2019).

Despite the theoretical benefits of K-12 problem-solving, teachers face many challenges as they attempt to implement PBL. Research increasingly suggests that teachers adapt their instructional strategies based on the realities of their local instructional environment (Li & Stylianides, 2018; Voet & De Wever, 2017). For example, while most K-12 teachers have autonomy within their classrooms, they do not control the school climate where they operate, which may not be conducive for PBL (Park & Ertmer, 2008). Additionally, teachers may struggle with allowing students the freedom to explore the content (Maxwell et al., 2005). Another component that becomes challenging for teachers is how to design authentic tasks (Revelle, 2019) and assess the open-ended nature of cases posed in PBL (Fyfe & Brown, 2020; Hung et al., 2019). In light of these documented challenges, one of the concerns of PBL is that it is too labor-intensive and impractical for K-12 teaching contexts (Hung et al., 2019). Indeed, large-scale studies and meta-analyses find variation in the fidelity of PBL once implemented in the classroom (Hung et al., 2019; Lazonder & Harmsen, 2016; Walker & Leary, 2009).

The aforementioned studies about PBL suggest that teachers are reticent to fully espouse these student-centered approaches and implement it with fidelity. Although strong in theory, the variety of implementation also adds to the debate as to whether or not the theory of PBL is a feasible instructional strategy in practice (Hung, 2011; Revelle, 2019). To date, various case studies have reported on the initial implementation of PBL and its effect on teachers' pedagogical beliefs (Liu et al., 2012), self-efficacy (Park & Ertmer, 2007), and other areas. While these empirical studies provide invaluable information as to teachers' experiences in the first year, very little research has looked at how teachers adapt to PBL over time. If fidelity is compromised and significant variations emerge, it follows that one might question the efficacy of PBL to produce reliable and sustainable learning outcomes (Hung et al., 2019; Lazonder & Harmsen, 2016). As such, a further understanding of how K-12 teachers adapt PBL is needed in order to best engender higher-order learning initiatives and to support problem-solving classroom strategies. To address this gap, this manuscript first begins by exploring the emergence of problem-solving in the K-12 context, including the theoretical tenets and the constructs of PBL. We then present a study that details how teachers describe their adaptations when implementing PBL over time.

Literature Review

Problem-Based Learning

Although the definition of 21st learning is somewhat ill-defined, many scholars and theorists agree it includes the ability to engage in information-gathering, sense-making from diverse learning resources, and collaboration. These skill sets are increasingly emphasized in society given the greater recognition of ill-structured problem-solving within domain practice (Mainert et al., 2019). These problems lack any pre-defined solution as many of the variables are latent within the context (Jonassen, 1997; Jonassen & Hung, 2008), such as the various perspectives and constraints inherent within the situation. These types of problems also require one to not be siloed in their approach but instead understand the case within a broader systems perspective (Grohs et al., 2018; Reed, 2016; Reed & Vallacher, 2019; Voet & De Wever, 2017). It is therefore difficult to categorically assess success; rather, the individuals and peers must justify the viability of the proposed solution in light of the elements within the case (Ju & Choi, 2017).

Given the dynamic nature of domain practice, educators are looking for ways to better develop problem-solving within K-12 classroom settings. One of the most common strategies is problem-based learning (PBL), which provides learners the opportunity to solve the types of problems that frequently occur within a domain. Although PBL's original implementation is difficult to trace, many agree that McMaster University was one of the first to enact it as a system-wide curriculum (Moallem et al., 2019). Rather than focus on didactic teaching, the faculty used clinical cases as the driver of medical education. Another change was to minimize the emphasis on large, end-of-year grades and instead focus on formative assessments needed to refine students' learning. Over time, PBL was applied as a way to engender specific learning skills needed within clinical settings, including reasoning skills (Barrows & Tamblyn, 1980), hypothesis testing (Loyens et al., 2006; Mamede et al., 2019), and others. It is argued these experiences better contextualize knowledge, which supports transfer (Kolodner et al., 1996; Pedersen & Liu, 2002; Tawfik & Kolodner, 2016).

PBL is designed to be a learner-centered curriculum that provides learners the autonomy to solve authentic problems. Rather than conflate it with traditional curriculum design approaches, Savery (2006) argues that characteristics of PBL include the following:

- Students guide their own learning.
- The ill-structured nature of the authentic case affords an opportunity for open inquiry.

- Given that the problems are ill-structured, the cases include an array of problems and related subjects.
- Students must be given an opportunity to work with their peers to solve the problem.
- Reflection is an important part of the learning process to consolidate the ideas encountered during inquiry.
- Rather than acting as sole disseminators of knowledge, teachers serve to facilitate students' individual learning and collaboration with their peers.

At the core of PBL is an authentic problem as a way to catalyze self-directed knowledge construction (Cho et al., 2015). As learners engage in inquiry, they must understand the case (problem representation) and develop solutions through iterative inquiry. Learners will seek out information and share it with their peers and identify areas of disagreement, which elucidate additional knowledge gaps. As groups seek to justify their position and reconcile their differences, research shows they engage in meaning-making and a shared mental model (Ertmer & Koehler, 2018). In contrast with a more lecture-based approach, learners are thus afforded the opportunity to engage in higher-order thinking skills as they synthesize diverse information sources with their peers. Research specifically documents problem-solving competencies such as causal reasoning (Goodin et al., 2019), question generation (Olney et al., 2012), analogical reasoning (Kolodner, 1997), and decision-making (Tawfik & Jonassen, 2013). Others argue that the authentic nature of the case also supports affective outcomes, such as motivation (Liu et al., 2012; Wijnen, Loyens, Wijnia, et al., 2017) and self-efficacy (Brown et al., 2013; Demirören et al., 2016).

PBL in K-12 contexts

As time progressed, practitioners beyond medical education began to adopt PBL within their own domains. To date, K-12 teachers have employed PBL in upper grade levels (Merritt et al., 2017) and in various subjects, including math, science, social studies, economics, and literacy (Goodnough & Cashion, 2006; Maxwell et al., 2005; Merritt et al., 2017; Revelle, 2019). In line with the previously mentioned meta-analyses, a number of studies in K-12 settings have found equivalent or better knowledge gains when comparing PBL to other instructional approaches (Merritt et al., 2017). Additionally, in some instances, teachers have especially noted the level of motivation and the quality of artifacts that students generate when learning with PBL. In addition to providing students with opportunities to excel and engage with the curriculum on a different level, Revelle (2019) found

that PBL enabled teachers to have a deeper engagement with the content, which led to a better instructional experience for the learners.

Beyond documented student learning outcomes, additional studies have explored how teachers implement PBL. For successful PBL implementations, teachers often need to structure and support students through the process (Li & Stylianides, 2018; Park & Ertmer, 2008). Although case studies have documented the benefits of PBL in K-12 education, research has also documented various barriers to implementing PBL in classrooms. One common barrier identified in the literature is a reticence by some teachers to change the classroom climate (Park & Ertmer, 2008). Indeed, teaching with PBL requires a substantial paradigm shift where the teacher is no longer the disseminator of knowledge but instead facilitates the process of learning for the students (Maxwell et al., 2005). In some instances, teachers are beholden to testing schedules, which drive their curriculum and instructional strategies. In turn, these teachers often have to adapt materials to fit their constraints. Additional obstacles include a lack of professional development and organizational direction in terms of school-wide curricula (Jerzembek & Murphy, 2013; Park & Ertmer, 2008). Furthermore, teachers sometimes have a difficult time identifying relevant issues and problems for their learners (Ng et al., 2014; Revelle, 2019). As such, the realities of K-12 instructional settings make it difficult for teachers to implement PBL with fidelity.

Research Questions

The above research describes how PBL outlines specific instructional processes that are derived from established learning theories. When completed with fidelity, the literature suggests that learners are able to engage in more complex forms of reasoning when compared with didactic approaches to teaching. Despite its theoretical basis, related research suggests that teachers often adapt their instructional strategies based on the realities of their K-12 classroom context, including size, technology resources, and other factors (Li & Stylianides, 2018; Voet & De Wever, 2017). While the literature has documented generally positive results of initial PBL implementations, less is known about the degree to which teachers adapt their usage of PBL over time. Some adaptations might include a refined approach to teaching strategies, while others might include significant diversions from the original PBL model. A better understanding of the changes teachers enact provides important insight as to fidelity adherence and thus the expected learning outcomes of PBL. Based on this gap, we proffer the following research question:

1. What are the adaptations that experienced PBL teachers identify in response to the challenges of K-12 teaching?

Methodology

This study employed an exploratory case study (Yin, 2017), which allowed the research team to address research gaps related to “the ‘how’ or ‘why’ questions concerning the phenomenon of interest” (Yazan, 2015, p. 138). Because the research on how teachers adapt PBL over time is limited, this approach helped to determine teachers’ PBL adaptations and their rationale for doing so.

Participants

Participants were experienced K-12 teachers who were all current or former students in a graduate-level instructional technology program at a comprehensive university within the southeastern region of the United States of America. In terms of recruitment, interested participants were initially asked to complete a brief eligibility survey. Of those twelve that completed the survey, eight were eligible to participate in interviews; others were excluded due to no K-12 experience with PBL or only one year in the profession. Of the eight potential participants, six agreed to be interviewed. The six participants who took part in the interviews held various teaching positions and represented different school districts all within the southeastern region of the United States of America. The sample size included three males and three females. Participants’ age range was largely homogenous, with one participant whose age fell outside the 33-44 year range. In order to take part in the study, participants had to have at least two years of experience with implementing PBL. Participants had an average of 15.3 years of teaching experience and 6.5 years of experience implementing PBL. The teachers taught a variety of subjects, including English language arts (ELA), reading, science, special education, and business. In terms of grade levels, one worked at the elementary level, two worked in middle schools, and three worked in high schools.

Instrumentation

The present study employed qualitative data collection in the form of semi-structured interviews, which were derived from the Tamim and Grant (2013) study that looked at how K-12 teachers implemented problem-solving strategies in the classroom. Example interview questions included: How do you define PBL? How has your definition of PBL changed over time? What do you perceive the role of the teacher to be in a PBL activity? When you plan a PBL activity, what

are the components that you include in your plan? How has your view on what to include in the plan changed over time? When learners encounter failure, how do you encourage them to engage in additional inquiry into the problem? The questions were semi-structured to give the participants opportunities to convey a narrative about their own journey of growth in PBL. The interviews were approximately one hour and were audio recorded in person by a member of the research team familiar with PBL.

Data Analysis

This exploratory case study used evolved grounded theory (J. Mills et al., 2006) as outlined by Corbin and Strauss (2008) to answer the research question. Although the literature has described first-year PBL implementations, no constructs describe the adaptations that emerge over time. This form of grounded theory thus allows this study to indicate the distinct processes and actions that are inherent to the phenomenon. In doing so, this qualitative approach develops an “explanation or understanding that are arrayed to show how the theory works” (Creswell, 2007, p. 85). Whereas traditional grounded theory moves forward as a “clean slate” and aims to be free from bias, an “evolved grounded theory approach” is sensitive to prior theory and literature, therefore “interweaving the literature throughout the process of evolved grounded theory as another voice contributing to the researcher’s theoretical reconstruction” (J. Mills et al., 2006, p. 29). Macdonald (2001) further argues that this allows an “extended and emphasized range of theoretically sensitizing concepts that must be attended to in the analysis of human action/interaction” (p. 136). Given that PBL is an instructional strategy that has a set of prescribed procedures and literature base, the researchers looked for and classified indications of pedagogical, attitudinal, and behavioral shifts among participants’ comments.

In line with similar exploratory case studies, the qualitative data was gathered from a sample size of six participants (Sockman, 2015). Each of the six original interviews were transcribed and checked against the original audio for accuracy by the two research assistants. The two research assistants then divided each transcript into line items as units of analysis, each representing unique ideas for coding. In line with an evolved grounded theory approach, the research team initially used an open-coding approach to determine emergent themes within and among the line items (J. Mills et al., 2006). For example, several line items revealed an attitude shift toward failure as part of the learning process rather than as something to be avoided. Other shifts related to self-directed learning, the teacher’s role, classroom culture, skills development, student reaction, the problem, tools and technology, assessment, limitations, and collaboration. With this

lens, the two research assistants identified nine and eleven unique codes, respectively. The assistants further defined their independent codes with exemplary quotes pulled from the line items. After this process, the two research assistants and one senior member of the research team discussed the codes and quotes to look for patterns, similarities, and discrepancies. Through discussion and negotiation, the team was able to condense and refine the codes to (a) four broad

themes based on when the adaptation happened and (b) eight subcodes that fit within the broad category. These eight codes identified a pattern of shifted emphasis on participants' pedagogies related to teaching PBL in year one versus year two (see Table 1).

The two research assistants completed a second round of analysis based on the eight axial codes and reached an agreement on 61% of the line items. After negotiating the

Code Categories	Codes
Adaptations prior to classroom instruction	1. More emphasis on redefining the learning space 2. More emphasis on upfront planning and design thinking
Adaptations in interactions with students	3. More emphasis on problem-solving skills over content knowledge 4. More emphasis on student control and teacher facilitation 5. More emphasis on embracing failure
Adaptations in technology	6. Technology as facilitating collaboration 7. Digital literacy
Adaptation after PBL instruction	8. Assessment

Table 1: Final Eight Axial Codes

discrepancies, the inter-rater reliability increased to 90%. A senior member of the research team reviewed the remaining 10% and determined a code to best fit each based on the team's definitions. Finally, the researcher who served as interviewer independently reviewed the prior rounds of coding. After round two of coding, the entire research team met for one final debriefing.

Results

More Emphasis on Redefining the Problem Space

One of the themes that emerged focused on how the teachers shifted the scope of PBL cases, especially relating to initial design and case authenticity. In terms of initial design, teachers described how the state standards served as the starting point for an authentic case. For example, Participant 6 (P6)

described how “generally speaking, I look at the standard” to start designing cases. Others such as P5 echoed this statement when she said her problems are “something that is tied to a standard.” As they gained more experience with PBL, the teachers also described how the cases increasingly caused them to rethink their definitions of authenticity and how to infuse additional context into the PBL experience. In terms of the problem space, P6 elaborated on how she increasingly designed cases to be “worlds in which we have to solve problems and things. And so I always make an attempt to try to give my students a real, authentic look at, you know, how they can use these skills.” As time went on, P1 similarly described questioning “what authenticity means and allowing students to have more voice in what's authentic to them. What communities are authentic or real or they participate in that aren't necessarily school. And allowing them to think about [it]. Maybe it is a club in school, but maybe also it's

a group that they participate with.” The cases, therefore, included a mix of state standards and local issues in which the students were situated. In doing so, authenticity was not just about designing a compelling case, but thinking through problems that were reflective of the community so students could develop their own voices and citizenship when solving problems.

Teachers described how they initially viewed the problems as smaller segments, but increasingly expanded the assigned case to accommodate the ill-structured nature of the authentic problem. For example, P2 noted that:

I define problem-based learning as giving authentic problems that exist in the content area, along with other disciplines that could be brought in that could help a student learn how to critically look at different kinds of issues and critically look at content that is being presented. It used to be that I would look at problem-based situations, problem-based learning as little scenarios. And ‘OK, we’re gonna do a problem-based activity’ And it would be more of a short-term kind of thing. As we have moved forward, I find that if you can infuse different aspects into a problem-based activity, that you get more leverage.

As she noted, the interdisciplinary view of the problem space inherently led to larger cases, which expanded the modules. In a similar vein, P3 described how she’s become more interdisciplinary in terms of the cases she designs as an ELA teacher: “And I’ve always tried to connect it to their science or social studies standards. But it’s, I don’t know, I feel like there’s so many other things out there that we could talk about. And like environmental, you know, issues in the real world. You know, getting them to branch out a little bit more into current events or things happening in the world or tap into some engineering, more engineering things. And not just be stuck to our fourth grade standard.” Although they started with a pre-defined standard, she described how the lens of authenticity moved her to think about related concepts from an interdisciplinary perspective.

More Emphasis on Upfront Planning and Design Thinking

In addition to shifting definitions of authenticity and problem scope, the participants indicated a trend toward greater upfront planning as to provide better structure and support for student-centered instruction. Indeed, PBL and other constructivist learning pedagogies are often met with trepidation among teachers because of perceived reduced teacher control (Noweski et al., 2012). Over the years, the participants in this study mitigated this issue by focusing more on upfront planning and design thinking to guide students along

their learning path while still giving them autonomy. This included considering resources, having empathy, and aligning the case elements with the students’ prior knowledge. In terms of resources, P1 described the challenge of planning for problem openness and the students’ need for structure:

I’m trying to think of the right word... more strictly and in a more... the better understanding of where students are gonna go off on a tangent and how to draw them back in or guide them on a more, more appropriate path for their questions. The teacher has to put in, the teacher has to be the front loader and the support system.

Other participants elaborated on upfront planning with concrete PBL components that they now prepared prior to implementation. P2 and P3, for instance, both referenced the challenge of finding optimal resources and how this required a significant amount of time. P5 reflected on generally including more components upfront to structure student success once implemented in the classroom:

Well, when I originally implemented it, it was mainly maybe just a standard and a task for the students to do. But now we’ve added more with vocabulary and rubrics, letting the kids see what it is that they need to do in order to have a, I would say, a passing grade for that particular project or problem-based learning activity. It’s just different things that we see that we needed to add to make it more productive on the students’ behalf.

As noted by the quotes above, upfront planning places the responsibility on the teacher to develop structures and logistics for PBL early to reduce confusion once students take ownership of their learning during class time.

As part of upfront planning, many noted espousing principles of design thinking. Although iterative stages of design thinking can vary, models commonly include the following: empathize, define, ideate, prototype, and test (Stefaniak, 2020). Most participants in this case especially demonstrated adherence to the first stage (empathy) prior to PBL activities. Empathy, as seen in the last section, is imperative to understanding the authenticity of problem space for the learners (Stefaniak, 2020). As an extension of that, participants also reported empathy in terms of getting to know and design for students’ personalities. P3, for example, adopted personality tests at the beginning of the school year to empathize with students and aid PBL group work later:

The first time I ever implemented a PBL and I just you know, you can get with a partner or group, whatever, make your own. And then kind of noticed, you

know, there were some weird groupings [...]. And so then you see kind of it. It really helps to start thinking about that and like, “OK, well, this kid gets really stressed. This kid actually perseveres. This kid sometimes needs a little more motivation.” And so when you have one of each in the group, then it’s not overloaded one way or the other.

While P3 employed personality tests to better understand students, P6 approached this in a slightly different way by focusing more on prior knowledge. He explained, “It gave me a really good opportunity to assess where my students were at and set them up for the type of learning that I was expecting them to be able to engage in in the classroom. You know, kind of like just a... almost like trust building exercises at the beginning of the semester.” These discussions reveal a trend toward teachers thinking as designers and empathizing with their students before PBL activities begin.

Norton and Hathaway (2015) asserted that “the design process is cyclical or iterative as new and existing designs are reworked until they fit the needs of others” (p. 8). In line with that assertion, some participants indicated that their design thinking mentality and iterations extended beyond upfront planning into the actual PBL implementation. Specifically, the participants appeared to adopt the iterative nature of design thinking as evidenced by their efforts to adapt and improve their PBL lesson plans. P4 explained that when PBL activities fail “you just, you know, make adjustments because [...] we’re in it for the kids and you got to think what’s in their best interest.” P5 approached iteration by advocating for “collaborating with other teachers or teachers in the same content area and asking ideas for your [...] problem-based learning.” When asked how he approached PBL activities, P1 remarked, “Depending on the standards, what the first thing is design thinking and the importance of going back and going back and testing your initial ideas.” P6 elaborated further:

And so, you know, that that revision process I found was so instrumental in my own career that I started putting it more and more often into the problem-based learning. It’s not that you throw something together and see if it works, but it’s more like you throw something together, you beta test it, and then you get to... then you make changes and then produce something that is actually kind of publishable or, you know, able to be demonstrated to a larger audience. So if it was anything, it was like finally completing that circle, you know, instead of just, you know, like, here’s the assignment, let’s see a product. So I think that’s shifted over time more than anything.

Based on the quotes above, it appears that these teachers have adopted the constructs of empathy and the iterations of design thinking to support their upfront planning, as well as their continuous improvement of PBL lesson plans.

More Emphasis on Problem-Solving Skills over Content Knowledge

When asked about ways in which their PBL instruction changed over time, participants noted an increasing desire to emphasize problem-solving skills over content. The specific skills noted by teachers included 21st century skills, iterative problem-solving, and knowledge transfer. For example, P3 evolved to see problem-solving skills and 21st century skills as the ultimate goal: “It’s not even [about] their final product. Like during the process, if I see kids going ‘Oh my gosh, I can’t believe that. Oh my gosh, look what I found.’ Like those ‘aha’ moments. That’s when I feel like, ‘OK, we’re getting somewhere.’” Although a prior theme described teachers building from the standard, participants described a realization that their job was no longer just to “impart knowledge on them [students] through like, you know, lectures or things like that” (P6); rather, the teacher became more focused on the students’ thought processes needed for problem-solving. P6 noted that as they gained more experience, “it’s not the content that I’m interested in, but the skills that the students develop in the process and the knowledge they gain about their learning and their ability to produce things that are beyond their own original thoughts.” P1 elaborated further when she said:

Which goes back to how much time should be really spent building in those thought processes and not... So students figure out how they think about things before you implement this big idea. [...] And I initially thought it should be one way, but I’ve opened up to the concept of students have to figure out how they have to think about things. And then you dive into the problem that you want them to solve or problems that you want them to solve.

Accordingly, the goal of teaching became to prepare effective problem solvers, students who “really look at the different ways that they can solve a problem and choose a better or a... a better choice for solving a problem” (P2). Interestingly, participant statements also pushed past the pedagogy shift for the teacher to emphasize the importance of transferability of those 21st century skills to other classes and problems. Comments like the following from P2 illustrate the shift:

My view has changed that it is important what we do, and that the things that we do are student-centered, and that the student learns and that the student can

explain. And if the student can go on and use what they learned in other areas of their academic courses, or if they can use it in other areas of their... of their career, then that's been successful. And I never really thought about that when I first started doing it. But it is important.

Similarly, P6 noted that he adheres to the standards in his planning process, but he's often "thinking beyond that to actual skills that a student would need to be able to survive in the real world." On the other end of the lesson planning process, P1 strategically used reflection to reinforce student self-awareness of their skill development:

That's all the reflection piece and students being able to actually say what they believe they learned from the experience and not necessarily what they learned from the project. It might be a tangential skill, but it should be transferable. I learned how to research. I learned how to build something, I learned how to use X tool and actually being able to take something away from the experience that they can use in another part of their education, regardless of what that is.

Rather than just focus on specific rote memorization of topics, the participants emphasized the importance of intentionally prioritizing how the content could be applied during problem-solving.

More Emphasis on Student Control and Teacher Facilitation

In line with prior literature, the coding also elucidated changes in the teacher-student dynamic; that is, teachers described how they still struggled to find the balance between student autonomy and teacher facilitation. In contrast with their early implementations of PBL, teachers came to encourage more self-directed learning, understand individual student needs, and embrace a co-learning model with students. As time progressed, they also noted the importance of facilitating through different approaches to reflection. In terms of espousing more self-direction in students, P2 commented on how her initial interactions with the students were increasingly more teacher-driven: "[At first] I would talk a lot, and I would share. And I still do share, you know, ways but I use a lot more student-centered discussion now. Much more student-centered discussion. Much more 'Well, what do you think or how would you approach this?' Or 'Why are you, you know, why are you doing this particular task this way?' And really more of a questioning and really listening to the students. So I have really moved more to... or a less from a teacher-centered 'let's talk about this' and to 'you talk and let me interject as I see I need to.'" Similarly, P1

commented, "Initially, I thought the role of the teacher was to push them along into one particular lane that I thought was supposed to provide the answer, and now I have more decidedly thought that my role as an instructor, my role as an instructional coach is to provide the structure for students to climb their way through that way more appropriately or more gradually... So originally it was I was told that I was going for it and it was a very strict process in what student should be completing." In some sense, this discussion of class time is the corollary of the comments describing teachers' upfront planning to impart structure. P1 went on to describe various tools he employed to provide that structure, but instead how he went the other direction and "overscripted" student learning at times. As he became more familiar with PBL, he described: "And in reflecting on that, I realized that students should be given more autonomy to figure out their process. [...] An explicit redirection is a method that's really easy, but it does take away the student agency and I'm definitely guilty of it."

Others commented how there was a need to be perceived as the expert, which was difficult to do given the open-ended nature of PBL and varying solution paths a student might explore. The teachers went on to describe the challenge of students at different levels and how difficult it was to manage their individual needs. P2 described how there were multiple students who wanted structure, as well as students who moved away from the goals of the case: "And I usually end up conferencing with both of those students to try to figure out exactly where they're going to go with a project." To address this issue, they learned over time not just to facilitate, but to view themselves as co-learners with the students: "But I think the teacher at the same time that they're facilitating and establishing the guidelines for the kids, they [teachers] have to be in that learning role as well and be able to accept new ideas from the students in PBL. When I was originally implementing it, I thought that the teacher just had to be in control of everything and guided the process step by step. And like I said before, instead of giving the kids free range and being able to think outside the box. I think that's how my view is changed now."

To support their interactions, teachers highlighted the importance of shared reflection to establish a shared mental model across teachers and students. While many expressed originally doing this at the end of instruction, they often described different adaptation strategies that emerged over time. In terms of an ad hoc approach at the beginning, P3 details how "I now do a little more brainstorming as a group. And that KWL kind of thing that I have them do at the beginning, I look at those a little more closely and we kind of have more of a class discussion where everyone has to share at least one thing they already know, so it kind of... And we

put them on a post-it note on the on a chart together. And so I can kind of see like... Even just one, if you're just telling me one detail or one fact or one thing, you think you know it. It's very telling on kids who are like getting it and kids who are still, you know, like really clueless. So a little more on the front end of building background knowledge." Others highlighted the importance of reflection as an important instructional strategy to mitigate potential issues: "And I'll tell you, you know, that really changed me, too. I hated doing reflections then. But, boy, I really see the value of looking back and saying, 'Well, what did I learn? What, you know,... what was it I was trying to learn, and what was good about this, and what would I do differently?' So I think that reflection is important for students as well" (P2). Although the reflection strategies are different, both helped to consider the classroom's collective learning gains and thus help manage the changing teacher and student dynamic.

More Emphasis on Embracing Failure

Depending on the structure and support used in PBL, student failure was described as something that teachers increasingly embraced as part of the instructional strategy. Teachers therefore expressed needing to change their classroom climate and mentality about failure during problem-solving. To support this, participants emphasized the need for embracing principles of the so-called "growth mindset" (Dweck, 2016) upfront with learners. P1 described how PBL shifts culture and perspectives on failure when she said: "I think it needs to be a decision because it's [PBL] pedagogically different than the way a lot of teachers that I've worked with teach. You have to build the culture in from the first day of school. The thought process has to be different. Emphasizing growth mindset, emphasizing not just failing but emphasizing the importance of what you do, do well, what students do well..." Similarly, others noted that failure was not just a cognitive activity, but part of the overall sustained change in the classroom climate: "It's not really something that you can say halfway through a semester. 'Oh, I'm going to do this in a couple of weeks' because if you drop that concept of now the student is in charge and now the student has to research then it throws off the entire culture of the class." (P1). For failure and struggle in PBL to be accepted, the classroom climate needs to welcome it. The data highlights that this change is not instantaneous, but requires setting the mindset from the beginning.

In addition to changing the climate, the participants talked about how failure is inherent in complex problem-solving and how it impacted different types of students. For example, one participant (P3) shared how a change in the climate was especially necessary for different populations of learners: "I have a lot of gifted kids in here. And so they're used to

immediate, like getting it every time. So we have to have the conversation that it's [success] not going to be immediate. You're going to have to research, and research means search again and again and again and again." While encouraging students to rebound from failure is critical, teachers similarly described the equally important need to be mindful of how failure was received by other populations:

My school is a high poverty school, and my kids have some issues with coping skills. And I mean, you know, that's just honest and true. Sometimes kids who are in those situations do not... if it's not working, they will just quit. And I think that that is something that problem-based learning helps a student to see - well, you know, you really don't have to quit when something is not working. You figure out a different way to make it work and you figure out a different way to approach the situation. And I think that problem-based learning is very valuable in that scenario. (P3)

While some expressed the benefits of failure, teachers also described adaptations to avoid frustration. A common practice that teachers used was conferencing with the learners. For example, P3 detailed, "I try to do a lot of conferencing and like check-ins, you know, so like I'll pop around to the groups kind of constantly or just kind of listen in. So when I hear them start to get frustrated or fail, of course, I always tell them, 'Come to me, you know, don't just sit there and freak out... Where are you in the process? What are your questions? What are you looking for? What are you struggling to look for? Do you think we need more resources or are you looking for something specific that's not here?' We just kind of conference about it." Another participant echoed this method for embracing failure: "And looking at, okay, why don't we, you know, maybe having them talk with even a teammate or a classmate or having them look at: Okay, let's brainstorm this and how, you know, how... Why do you think this happened and how can we, you know, how can we look at this a different way? But really mostly mini-conferences is what I've used in the past" (P2). As such, a common method of helping students embrace failure once it has occurred is through this conferencing method.

Technology as Facilitating Collaboration

Another recurring theme that emerged throughout the interviews was the use of technology in the classroom. When asked to elaborate on how their views on technology changed, participants especially noted they had adopted tools that supported collaboration and sharing of resources. For instance, P1 noted that she shifted her selection of collaborative specific tools because they "can be used really

well to communicate if it's a group project or a one-on-one. Whereas a single student project, that's a really good open way for students to communicate with each other and then for teachers to check in and communicate it with students and then production". When asked why the shift towards more collaborative technology, P6 elaborated:

I specifically like that because then I have groups that can work together that are not geographically bound. It's not like 'Let's go over to Susie's house and make popcorn and make a poster.' It's more like, you know, can I work, you know, with other members of my group to produce this in in a virtual atmosphere like environment where like... it's easy to look back and kind of see the revision history, to see like who's pulling their weight and who's not kind of thing.

Although various participants noted the increased use and access to collaborative technology to be a positive in the classroom, one participant offered a negative side to the use of technology in PBL over time. For example, the use of many different technology tools in the classroom became intimidating from a classroom management perspective. P5 expressed this fear about technology in PBL:

I think that's what has, I guess, scared a lot of teachers off and especially with the integration of technology, because they don't... some teachers don't feel comfortable with using the different technology tools, so it limits their use in classroom because I guess they feel that if they don't know how to master it and keep tabs on what all the students are doing and be the expert in every aspect, then it kind of scares them where they're not... they don't want to venture into those types of projects.

The data above indicate the use of technology in the classroom allows PBL teachers to explore different avenues within and outside the classroom. It also enables teachers to support students across time/space barriers through the ability to collaborate with one another. Additionally, technology allows students to research and find their own resources during inquiry, along with offering teachers more resources than were previously accessible.

Digital Literacy

As it relates to technology, teachers also noted a shift in their approaches to digital literacy; that is, the students' ability to use information resources during inquiry (Porat et al., 2018). Whereas digital literacy is important for inquiry during PBL, the teachers commented on its impact on teacher/student roles and information overload. As the participants

described the shifting dynamic between teacher and student roles, they shared how they now make a point to include instruction on the information-seeking process:

The discernment of the information that's being presented to you, is this, you know, is this information that is, you know, true information that I can use in my project, or is it something that I need to, you know, to really question? And I think that there is value in that, too, because, you know, you're learning when you're doing that. (P2)

Beyond discernment of information, P3 noted that students were increasingly seeking technologies that helped to collect their inquiry artifacts: "They're [the students] using, you know, the Internet or, like I said, we combine the resources into a page that they can access through their county logins and on our media center platform. So for research, definitely". To that end, other participants highlighted how digital literacy coincided with the shifting dynamic between teacher and student roles. Interestingly, some noted how PBL often went beyond their own content knowledge; hence, digital literacy instruction was needed so as not to inhibit student learning:

There's so much information out there, so many learning tools that the kids can use. And so many sources for information and the teacher couldn't possibly just master all of it. So they have to be in a way where they can accept new ideas or things that they didn't know about a particular subject. (P5)

Although digital literacy was deemed important, P2 further elaborated on how digital literacy included inherent challenges:

We have so many more resources. And that also creates a problem. It creates a wonderful variety when you have online resources and those things that you can look at virtually and those things that you can do online. But it also creates a situation where you are thrust in to helping students to discern... what is... what is it I really am looking at, and what and how... how can I approach, you know, creating this... this project or solving this problem and actually using their own resources, their brains to work together? I think that that has kind of been a two-edged sword there. You know, as we moved forward with more technology, I think you have to be responsible with that when you're working in any kind of a problem-based situation that you don't get caught up in: 'Oh well let me just look at this and see what this, you know, what this says'.

In a similar vein, P5 detailed how:

It was like teachers maybe knew how to solve a particular problem their way. And you would, teachers were mainly guiding the students to fit their logic, or how they were thinking about a problem instead of thinking outside of the box. Kind of guiding them to their own solution. Well, but now, you know, with like I said earlier, with so many different tools and so many sources of information and different ways to solve problems, you know, I see where that is expanded for the students and can increase their thinking and mindset about approaching problems.

Whereas digital literacy has traditionally been described in PBL as seeking information online, the teachers described the importance of seeing digital literacy as (a) a way of going beyond the mental model of the instructor and (b) a means of constructing knowledge through iterative inquiry

Assessment

Towards the end of the PBL unit, participants remarked on the changes of PBL assessment. Similar to prior studies of first-year implementation of PBL, the data suggests a degree of variability and change about how to judge the student artifacts where there is no predefined answer. In line with the prior comments from upfront work (More emphasis on upfront planning and design thinking theme), many emphasized the increasing importance of rubrics to provide a baseline for ill-structured problems assessment. P6 described how initial rubrics for PBL included a set of very specific items: “At the very beginning of, you know, the PBL experience, I clearly articulated how I was going to score the assignment so that it wasn’t in doubt. And like I said, those... that rubric was very small. You know [...] like one of them would be like it appropriately illustrates the theme... and develops the theme of whatever it is we were looking at. So there was only usually about three or four really important categories that needed to be done” (P5). Others described how the rubrics underwent changes to accommodate their changing case designs and expectations of learning outcomes. For example, P1 shared his change in perspective in terms of what should be assessed:

I’ve always used rubrics, but the rubrics have changed to be based on a level work. It’s not based on things... a level where it used to be you completed it. [Before it was] ‘it got completed really well and it looks really cool and it’s thought out and completed.’ Versus [a] level of work now is ‘Did you attempt to complete something that you didn’t maybe know, you couldn’t push yourself and ultimately come up with a solution to a problem even if you weren’t able to build it? Do you

have those other solutions because you’ve attempted and things didn’t work out so well that time.’ And I place more value now on attempting understanding and growth and learning as opposed to completion.

In this view, the assessments were not just about the content, but about recognizing the student’s ability to experiment through their thought process. Similarly, P5 described how her assessment shifted as she assigned different tasks: “Well, when I originally started... it was just mainly looking at if the kids, I think, we had like maybe a chart that had a particular task that the kids had to figure out. And you received so many points for that particular, you know, that particular task, when I first started. So it was mainly just a check off to see if the kid had completed those particular tasks. Now moving towards the rubric where the kids see that there are varying levels of performance in the activity.” Similar to the ill-structured nature of the problem, that data indicate teachers seem to embrace a more open-ended approach to their assessment strategies.

Discussion

The literature on PBL implementations describes how educators often adapt their instruction based on the contextual constraints of their classroom, including standards, administrative support, technology, and other factors (Ertmer et al., 2009; Hung et al., 2019). Research suggests that teachers adapt this instructional strategy to meet the unique needs of their environment (Lazonder & Harmsen, 2016; Walker & Leary, 2009), which has caused some to highlight “theory to reality” challenges and question the fidelity of PBL in modern learning contexts (Hung, 2011; Lazonder & Harmsen, 2016). Various studies have looked at the opportunities and challenges of first-year implementations, but the literature is less clear on how experienced teachers adapt their instruction and their adherence to the initial PBL constructs. Future study in this area would provide insight into the ways in which teachers diverge from the initial PBL model outlined by theorists and its potential impact on learning outcomes. Given the open-ended nature of the gap, this research study employed an exploratory case study approach and analyzed data using grounded theory, which elucidated adaptations at various stages of instruction. Prior to implementation, themes were focused on (a) reimagining the problem scope and (b) design thinking. During classroom time, teachers described shifting perspectives in terms of the following: (a) problem-solving skills over content knowledge, (b) student control and teacher facilitation, and (c) embracing failure. As it relates to technology, teachers suggested (a) more adoption trends towards collaborative tools, while also describing

(b) opportunities and challenges with digital literacy. Finally, teachers indicated diverse approaches to assessment in light of the ill-structured problems posed by PBL.

Adaptations Prior to Classroom Instruction

The first codes (redesigning the problem space; upfront planning and design thinking) were largely focused on instructional preparation prior to classroom instruction. What is noteworthy in this study is how teachers described adapting the assigned case and broadening the problem space as they gained more experience with PBL. In contrast to initial implementations that focused PBL problems around a core set of topics, the teachers detailed how they began to move towards more authentic and interdisciplinary problems. This supports the view of Park and Ertmer (2008) that expert PBL teachers were more likely to apply multidisciplinary efforts during instruction. More recently, Stehle & Peters-Burton (2019) posited that “designing real-world problem scenarios for the classroom provides a framework by which students can engage in 21st Century learning” (p. 4). However, extant research indicates that program area teachers are often siloed in their domains during professional development (PD) (R. Mills et al., 2020; Voet & De Wever, 2017). PD sessions could instead encourage case-building across disciplinary areas. In some ways, this aligns with the recent “STEAM” trend as art teachers are collaborating with STEM instructors. Because the role of the librarian has changed to emphasize more instructional design competencies (Cox & Corral, 2013; Kuhlthau, 2010), this may also position the librarian to make interdisciplinary connections during the case design process.

As teachers gained more expertise, they described the need for upfront planning to counterbalance the open-ended nature of class time afforded by PBL. They described this upfront planning as not only developing the case, but also anticipating resources and establishing initial guidelines to avoid digressions that could derail the PBL module. What is also notable is how teachers described adopting more of a design thinking approach. This extends the prior literature of iterative planning in PBL (Rillero & Camposeco, 2018; Rovers et al., 2018), but especially highlights the empathy construct of design thinking as the teachers gained PBL experience. The present study reinforces prior studies that show that as teachers gain more expertise with problem-solving, they leverage PBL for 21st century skills development alongside content standards. The transition from a focus on content to skills is a potentially difficult change for teachers; it amounts to a pedagogical paradigm shift for many teachers who were often trained for teacher-centric classrooms (Ertmer & Simons, 2006; Sproken-Smith & Harland, 2009). These skills are further congruent with Stehle & Peters-Burton’s (2019) study findings that “placing students in groups, structuring

feedback, and having students design a final project for a particular audience” (p. 11) are teacher behaviors that promote problem-solving skills.

Adaptations During Classroom Instruction

Adaptations in Interactions with students

Another set of codes (i.e., more emphasis on problem-solving skills over content knowledge, more emphasis on student control and teacher facilitation, and more emphasis on embracing failure) dealt with the adaptations that teachers enacted during their classroom interactions with students. In terms of the problem-solving skills over content knowledge theme, participants discussed how it was important for students to not only learn the subject matter but to develop problem-solving skills that could be transferred “in the real world.” As noted earlier, the cases were designed with state standards in mind, but increasingly emphasized authenticity and opportunities for knowledge transfer.

Another component of the adaptations during instruction relates to the need for the classroom climate to change, especially as it related to (a) student control and teacher facilitation and (b) more emphasis on embracing failure. As to the former, participants discussed the challenges of providing students freedom in problem-solving and facilitation strategies, which is consistent with prior studies (Maxwell et al., 2005; Revelle, 2019; Tamim & Grant, 2013). As time progressed, they found that when they embraced a co-model of learning with their students to account for the ill-structured nature of problems, it resulted in a richer PBL experience and allowed them to manage the teacher-student dynamic better. Indeed, part of this change relates to the importance of guiding the learners through the inquiry process. Teachers must provide learners with the optimal level of scaffolding (Hmelo-Silver & Barrows, 2006; Kim et al., 2019; Lazonder & Harmsen, 2016), which can be difficult to balance. Participants noted that they initially offered too much guidance or would explicitly redirect students when it was not completely necessary. As time progressed, teachers would ask questions that were more open-ended and encouraged students to revisit their reasoning process. The findings, therefore, coincide with prior studies which show that open-ended questions are more likely to encourage future iteration from students (Furtak, Bakeman, & Buell, 2018).

The final adaptation described teachers’ changing approach to embracing failure and how it impacted the overall classroom climate. Some students are not well-equipped to deal with failure because they are used to understanding the content in a well-structured and linear approach. One direct method that participants used to address failures was conferencing. These conferences involved teachers working

directly with students encountering struggle through pointed questions to provide them with formative feedback and encouragement. In a sense, this approach serves as a method for teachers to help guide the learners through failure, iterate their problem-solving, and consolidate their attempts into a more meaningful mental model (Kapur, 2018).

Adaptations in Technology

The research also described interesting PBL adaptations relating to the shifting role of technology. Indeed, other studies have explored how teachers try to align their technology and instructional strategy with desired learning outcomes (Fidan & Tuncel, 2019; Metcalf et al., 2018; Rovers et al., 2018). What is unique in this study is that educators especially described a migration towards technology that aided computer-supported collaborative learning (CSCL). This study, therefore, reinforces prior research that emphasizes the importance of collaborative learning in PBL. In a recent overview, Jeong and Hmelo-Silver (2019) describe how CSCL literature is often segmented into three broad sections: cognitive, process, and affective. In line with their results, the data seemed to indicate a preference for more process supportive tools. In many ways, the need to manage the collaborative process through technology is closely related to the themes focused on problem-solving skills and student control. The teachers also alluded to how the collaborative technologies posed potential classroom management issues, which they suggest caused other teachers in their district to avoid PBL. While this provides clarity on teachers' needs for this instructional strategy, research suggests a reduced likelihood of PBL being used in the classroom if a teacher does not feel confident in using technology (Ertmer et al., 2012).

The final technology theme is related to digital literacy. In line with prior literature, the teachers highlighted their growing emphasis on information-seeking inherent in PBL (Cleovoulou & Beach, 2019; Glazewski & Hmelo-Silver, 2018; Pedaste et al., 2015). Given that inquiry is an important element of knowledge construction, it follows that students are responsible for seeking out resources that support their problem-solving processes. While studies have begun to explore digital literacy in PBL (Frerejean et al., 2019; Zhang et al., 2017), two interesting ideas emerged that address gaps in the literature. First, the experienced PBL teachers described how the overwhelming nature of information highlighted the knowledge gaps within themselves. Teachers further discussed the challenge of balancing the inherent decision-making processes within digital literacy as students developed their own mental models, while also facilitating inquiry that was potentially beyond the teacher's understanding of the phenomenon. The teachers described the importance of upfront planning and embracing a co-learning model with

students. This is noteworthy because many PBL models are often approached from the expert-novice mindset, which positions teachers as the experts that guide the student. The current study suggests that teachers need professional development and models that support facilitation when the students branch out beyond the teacher's mental model.

Adaptation After PBL Instruction

The final coding detailed the shifting nature of PBL assessment over time. Indeed, literature increasingly suggests that assessment is one of the most challenging elements of PBL given the complexities of ill-structured problems and how PBL changes classroom roles (Odell et al., 2019; Tamim & Grant, 2013; Wijnen, Loyens, Smeets, et al., 2017). In contrast to more well-structured problems, the parameters for grading in PBL are often nebulous given the various solutions that could be devised. Teachers cite challenges when required to assign traditional points and grades to open-ended problems, and some have even described its impact as a threat to PBL fidelity (Odell et al., 2019). Research suggests that this is even more complicated when alternative artifacts (i.e., concept maps) are submitted at the end of a PBL module (Ackermans et al., 2019; Giabbanelli et al., 2019; Metcalf et al., 2018). In the current study, teachers shared similar challenges about assessment in PBL and their corresponding adaptations. One of the first suggestions included how the rubrics became more open-ended over time, which seemed to coincide with earlier statements about how problems became broader and more interdisciplinary. Finally, others described how their assessment strategies included additional attributes focused on personal growth and affective elements.

The results have important implications for teachers as they gain additional experience with PBL. In the traditional view of PBL, assessment was often tied to mastery of the content, which is similar in nature to more didactic approaches focused on well-structured problems. More recent literature has explored alternative forms of assessment, such as "sliding scale" rubrics based on individual student needs (Mahmood & Jacobo, 2019), self-assessments (Caswell, 2019), and others. As instruction becomes increasingly tied to state standards, it may be difficult to fully document student success from a content-only model. Given that PBL emphasizes iterative problem-solving, educators could also use formative approaches to capture affective learning outcomes, such as motivation, self-efficacy, and persistence.

Limitations and Future Studies

While this study addresses a gap as it relates to experienced K-12 teachers and PBL, there are additional research opportunities. Due to the exploratory nature of the case

study, we interviewed participants across various grades. It is possible that PBL is implemented differently for early-stage learners when compared with higher grade levels given learners' cognitive development and need for scaffolding. A follow-up study could bound the case study around a specific grade or K-12 subject (e.g., STEM, language arts, etc.). A related study could also look at differences in the teachers themselves. The current study explored how K-12 teachers familiar with PBL adapted their strategy over time, which is more of a reflective approach. However, related research shows that teachers go through various stages in their expertise (McIntyre et al., 2017; McIntyre & Foulsham, 2018). A future study could thus compare the fidelity of PBL between novice, emerging practitioners, and more seasoned teachers. This approach could have implications for targeted professional development, which is important for teacher training (Herman, 2012; Peterson & Scharber, 2018).

An additional study could look at how experienced teachers adapt their problem-solving within specific domains. It is possible that teachers approach PBL differently based on the complexities and problems within the subject. For example, the engineering domain are often posed with decision-making problems, while the law domain might include more ethical dilemmas (Jonassen & Hung, 2008). It is possible that the nature of the problem might influence teacher decisions, such as case design and assessment strategies. In a similar vein, the results are likely influenced by the K-12 context explored within this study. For example, one might expect the upfront planning and design thinking iterations to look different when preparing for secondary students compared to medical students. Future studies could explore the degree to which these themes are recurrent across different PBL contexts.

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Andrew A. Tawfik, PhD, is an Assistant Professor of Instructional Design & Technology at the University of Memphis, where he also serves as the director for the Instructional Design & Technology Studio. His research interests include problem-based learning, case-based reasoning, case library instructional design, and computer-supported collaborative learning.

Jaclyn Gish-Lieberman is a research assistant and doctoral student in the Instructional Design & Technology program at the University of Memphis. Her research interests include

teacher education, English for Specific Purposes (ESP), micro-credentials, community of practice, and adult learning theory. For over ten years she has conducted ESP workshops as a US Department of State English Language Fellow and Specialist in Indonesia, Ukraine, Sri Lanka, and Vietnam.

Jessica Gatewood is a research assistant and master's candidate within the Instructional Design & Technology program at the University of Memphis. Her research interests include artificial intelligent tutoring systems, usability testing, problem-based learning, and computer-supported collaborative learning.

T. Logan Arrington is an Assistant Professor of Instructional Technology in the Department of Educational Technology and Foundations at the University of West Georgia, where he teaches graduate-level courses on Instructional Design and Human Performance Improvement. Logan's research interests focus on failure-based instructional strategies, professional issues in the field of Instructional Design and Technology, and authentic learning opportunities for under-represented groups, specifically rural students.